A CONTAINER STUFFING ALGORITHM FOR RECTANGULAR SOLIDS WHEN VOIDS MAY BE REQUIRED

Napoleon Bonaparte Nelson

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A CONTAINER STUFFING ALGORITHM FOR RECTANGULAR SOLIDS WHEN VOIDS MAY BE REQUIRED

by

Napoleon Bonaparte Nelson III

September 1979

Thesis Advisor: A. W. McMasters

Approved for public release; distribution unlimited.

T190354

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*) A Container Stuffing Algorithm for Rectangular Solids When Voids May Be Required	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1979
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Napoleon Bonaparte Nelson III	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	12. REPORT DATE September 1979
	13. NUMBER OF PAGES 112
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)	15. SECURITY CLASS. (*of this report*) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Containerization, Loading, Algorithm, Palletizing

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

An algorithm was designed to load different sized rectangular solids into a container. It allows the option of forming pallets of material before loading the container. The algorithm will permit loading of cargo that may or may not be used as load bearing support for other cargo. Cargo is allowed to be rotated if desired to improve efficiency and both the pallets and the shipping container may contain

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601 |

"voids" or volumes in which cargo is not permitted. A test of the algorithm utilizing an actual cargo list showed two-dimension (area) efficiencies of 95% and three-dimension (volume) efficiencies of 89%.

Approved for public release; distribution unlimited.

A Container Stuffing Algorithm For Rectangular Solids When Voids May Be Required

by

Napoleon Bonaparte Nelson III
Lieutenant Commander, Supply Corps, United States Navy
B.S., Georgia Institute of Technology, 1966

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1979

N3645
c.1

ABSTRACT

An algorithm was designed to load different sized rectangular solids into a container. It allows the option of forming pallets of material before loading the container. The algorithm will permit loading of cargo that may or may not be used as load bearing support for other cargo. Cargo is allowed to be rotated if desired to improve efficiency and both the pallets and the shipping container may contain "voids" or volumes in which cargo is not permitted. A test of the algorithm utilizing an actual cargo list showed two-dimension (area) efficiencies of 95% and three-dimension (volume) efficiencies of 89%.

TABLE OF CONTENTS

I. INTRODUCTION - 8

A. BACKGROUND - 8

B. THE NEED FOR AN ALGORITHM - - - - - - - - - - - 9

C. THE LOADING PROBLEM - - - - - - - - - - - - - - 11

D. THE CONTAINER STUFFING PROBLEM - - - - - - - - - 13

E. RELIANCE ON HEURISTICS - - - - - - - - - - - - - 16

II. OBJECTIVES AND SCOPE - - - - - - - - - - - - - - - - - 17

III. THE STUFFING ALGORITHM - - - - - - - - - - - - - - - 18

A. GENERAL DESCRIPTION - - - - - - - - - - - - - - 18

B. MEASURE OF EFFECTIVENESS - - - - - - - - - - - - 19

C. PREVIEW OF THE ALGORITHM - - - - - - - - - - - - 20

D. NOTATION AND DESCRIPTION OF MATRICES - - - - - 25

E. EXACT STATEMENT OF THE STUFFING ALGORITHM - - 29

F. SAMPLE TWO-DIMENSIONAL PROBLEM - - - - - - - - - 33

G. OPTIMIZATION - - - - - - - - - - - - - - - - - - - 40

H. OBTAINING BETTER SOLUTIONS - - - - - - - - - - - 41

IV. VERIFICATION - 42

A. RELATED ALGORITHMS - - - - - - - - - - - - - - - 42

B. SAMPLE DATA - - - - - - - - - - - - - - - - - - - 43

C. SAMPLE DATA RESULTS - - - - - - - - - - - - - - 43

D. ANALYSIS OF VARIANCE - - - - - - - - - - - - - - 45

E. RANGE TEST AND CONFIDENCE LIMITS - - - - - - - 45

F. DISCUSSION AND HEURISTICS - - - - - - - - - - - 46

V. CONCLUSIONS AND RECOMMENDATIONS - - - - - - - - - - 47

COMPUTER PROGRAM - 77

LIST OF REFERENCES -110

INITIAL DISTRIBUTION LIST - - - - - - - - - - - - - - - - -112

LIST OF TABLES

I. Sample Data - 48

II. Statistics on Loading Sample Data (Without Standard Pallets) - - - - - - - - - - - - 51

III. Statistics on Loading Sample Data (With Standard Pallets) - - - - - - - - - - - - - - 52

IV. Sample Data Sorted by Area - - - - - - - - - - - - 53

V. Pallet One Configuration (Without Standard Pallets) - - - - - - - - - - - - 56

VI. Summary of All Pallets Loaded (Without Standard Pallets) - - - - - - - - - - - - 57

VII. Container Configuration (Without Standard Pallets) - - - - - - - - - - - - 61

VIII. Sample Data Sorted by Height - - - - - - - - - - - 68

IX. Pallet One Configuration (With Standard Pallets) - - - - - - - - - - - - - - 71

X. Summary of All Pallets Loaded (With Standard Pallets) - - - - - - - - - - - - - - 72

XI. Container Configuration (With Standard Pallets) - - - - - - - - - - - - - - 73

XII. Newman-Keuls Range Test Results and Confidence Intervals (Without Standard Pallets) - - - - - - - - - - - - 75

XIII. Newman-Keuls Range Test Results and Confidence Intervals (With Standard Pallets) - - - - - - - - - - - - - - 76

LIST OF FIGURES

1. Matrix of Loading Problems - - - - - - - - - - - - - - - - 12

2. Possible Orientations of Box within Pallet/Container - 14

3. Possible Origins for Placing Incoming Boxes on Pallet - 21

4. Example Problem - 36

I. INTRODUCTION

A. BACKGROUND

Computerized analyses and computer assisted algorithms have been utilized extensively in most areas of transportation systems. The military, in particular, has relied heavily on loading simulations and computer assisted algorithms to predict the assets required to meet a given transportation demand [2]. However, no reference can be found which indicates that these computer techniques have been accurate, flexible, or descriptive enough to act as an actual blueprint for loading multicommodity cargo into the transportation container, be it a sea van, truck or airplane. The actual loading is apparently still performed, for the most part, by personnel without the help of computers.

In an attempt to partially fill this void, an heuristic algorithm was developed which should be efficient and precise enough to use as an actual blueprint for loading one, two, or three dimension cargo. This algorithm exceeded the unassisted performance of loading crews for sample data; is adaptable to any shaped container; permits container "voids" or volumes where cargo can not be loaded (i.e., refrigeration vests, reserved space, etc.); recognizes that some cargo may be rotated for increased efficiency while other cargo can not be rotated; permits only weight bearing cargo to be used as a base upon which to stack other cargo; and,

allows the optional requirement that smaller boxes must be loaded on a standard pallet prior to being placed into the container (the formal term of placing cargo into the container is 'stuffing' as opposed to 'palletizing' the cargo prior to stuffing). In addition, the algorithm is capable of solving a large problem within several computer (CPU) minutes and requires relatively little main core memory.

The algorithm described above is hereafter designated as the container stuffing algorithm. The need for such an algorithm is discussed in the next section.

B. THE NEED FOR AN ALGORITHM

The advent of mechanized warehouses, sharply increasing transportation costs, and increased availability of computers greatly increases the potential return on investment that is expected to be realized from the implementation of an algorithm as described above.

Mechanized warehouses permit extremely rapid, efficient, and flexible issuance of material from the warehouse. Material in a mechanized warehouse is received, stored, and issued with very little manual intervention by the warehouseman. This is accomplished by the use of real time data bases, one hundred percent visibility within the receipt-issuance cycle, and complete knowledge of the item characteristics (weights, dimensions, etc.) of the material being stored. However, some of the efficiency gained by the mechanized warehouse is lost once the material is dispatched from the mechanized warehouse. For example, the material must be

staged in the shipping section prior to the actual loading of the material into a shipment container. This is necessary because of the current inability to accurately predict necessary transportation assets and because of the need by the loading personnel to physically view and study the physical characteristics of the cargo prior to commencement of the loading process. By eliminating the need for staging material prior to shipment, savings could be realized in manpower necessary to actually load the material, in staging cost, and in costs associated with positioning the container prior to commencement of the loading. Additionally, there is a cost associated with delaying release of the container pending completion of documentation which must be prepared after the cargo is loaded but prior to releasing the container.

Considerable savings could also be realized if greater efficiency of cargo volume to container volume were possible. As one specific example, if Naval Supply Center, Oakland, California, could increase its efficiency for shipments to Japan and Philippines (705,400 cubic feet or 17,635 measurement tons per year) from the current rate of 80% to, say, 87%, a yearly savings of transportation costs would be approximately $266,000 [12].

The algorithm developed to satisfy these requirements will be discussed in detail after the next section which briefly discusses the generic operations research problem which is becoming known as the loading problem [3].

C. THE LOADING PROBLEM

In order to understand the stuffing problem it is first necessary to review its superset, the loading problem. The generalized loading problem is one in which items, $I_i \varepsilon I$ of magnitude q_i and value v_i, are placed in containers, $C_j \varepsilon C$ capacity c_j and cost of d_j. The sets I and C contain, respectively, all items to be loaded and all containers used in the loading.

The problem may indicate:

a. $\sum_{j \varepsilon C} c_j \geq \sum_{i \varepsilon I} q_i$ and all items are loaded, or

b. $\sum_{j \varepsilon C} c_j \geq \sum_{i \varepsilon I} q_i$ and all items need not be loaded; or

$\sum_{j \varepsilon C} c_j < \sum_{i \varepsilon I} q_i$.

The objective may be to

a. minimize $\sum_{i \varepsilon S} (q_i \cdot v_i)$ where S is the set of all items not loaded $(S \varepsilon I)$;

b. minimize $\sum_{j \varepsilon C} (c_j \cdot d_j)$

A matrix of the objective functions and problem statement is shown below and summarizes the various possible problems. An asterisk indicates that the assumption of additivity has been made. Under this assumption, whenever $\sum_{i \varepsilon I} q_i \leq \sum_{j \varepsilon C} c_j$, all i items may be loaded in the j containers; that is, the assumption of additivity allows the quantities which are being loaded to be added together without geometrical considerations of individual containers.

This assumption is easily made when measurements are in terms of money, weights, liquid volume, or when $\max_{i \varepsilon I}(q_i) << \min_{j \varepsilon C}(c_j)$ and prior palletization is not used.

		Problem Statement	
		a	b
Objective	a	1	2^*, 3
	b	3^*, 4	5

Figure 1. Loading Problem Subsets

Problem 2^* is the classical multidimensional knapsack loading problem which has been extensively analyzed [8]. Problem 3^* has been solved for the case where $c_k = c_j$ for all k and j by Eilon and Christofides [3]. The Problem 3 solution for the case where items I are rectangular solids was developed by Gilmore and Gomory who used very large scale integer programming techniques [7]. The Problem 3 solution where $q_i = q_k$ for all i, k and items I were rectangular solids with one set of common dimensions was given by Seam and Sivazlian [10]. Problem 4 solution where items I were rectangular solids was presented by DeSha [2]. The Problem 4 solution for the case where items I were parallelepipeds and C was a single container was given by Galata and Stoyan [4]. This paper is concerned with a specific subset of Problem 4 called herein the container stuffing problem which is a representation of the generalized method typically

used to ship cargo. Although the problem was formulated in terms of a shipping problem, it may be easily expanded to solve related problems such as those presented by Brown [1].

D. THE CONTAINER STUFFING PROBLEM

This problem is one in which n boxes of size BOX_j are to be loaded onto pallets of capacity p_k, which are, in turn, loaded (stuffed) into containers, C_i, of capacity c_i. In the problem $BOX_j \leq p_k \leq c_i$ for all i, k and $\sum_j BOX_j \leq \sum_k p_k \leq \sum_i c_i$ with an objective of minimizing the number of containers required to load a given series of BOX_j, $j=(1,n)$. Because of the relative closeness (in size) of BOX_j to p_k and p_k to c_i, geometric considerations are extremely important in obtaining a feasible solution to the minimization problem; and, thus an elementary but important constraint must be addressed: none of the boxes (pallets, containers) may overlap into the space occupied by another box (pallet, container).

A successful practicable solution to this problem must also consider these following points. A rectangular solid box may be loaded into a container six different ways depending on the relative positioning of the moving coordinate system (x', y', z') associated with the box and the fixed coordinate system (x, y, z) associated with the container. It is assumed the container has its "origin" located at position (0, 0, 0) with length, width, and height in the x, y, z direction. Figure 2 shows the six possible orientations of a box in a container. These degrees of freedom

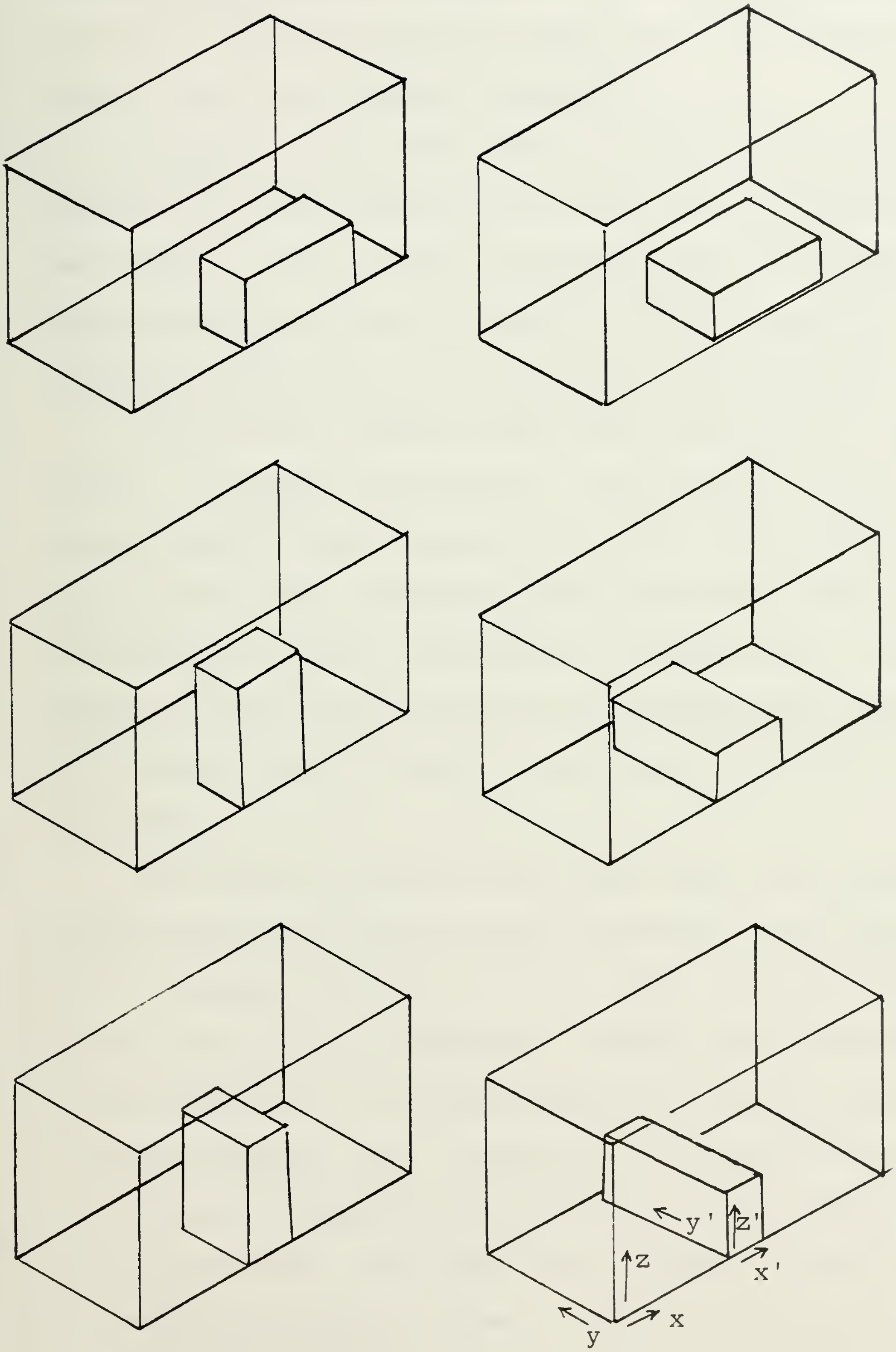


Figure 2. Possible Orientation of a Box within a Pallet/Container.

permit $n!6^n$ possible sequences for loading n boxes. For instance, six boxes may be loaded into a container in more than 33 million different sequences.

Because of this vast number of sequences, a practicable solution must be descriptive as well as prescriptive. It must define not only the sequence of the loading but also the relative position of each box in the pallet and the relative position of each pallet in the container.

Fortunately, certain real world constraints reduce the number of feasible solutions. The nature of some of the boxes requires that the box be loaded "this side up", that is, the box has a predetermined orientation (this reduces the problem to only two possible orientations). Also, the boxes have different load bearing capabilities resulting in the larger, heavier boxes being placed near the bottom of the stack.

The loaded containers must meet specified maximum weights and distributed weight parameters and hence may not end up being completely filled. Also, some containers require that voids be reserved to permit air circulation around vents, or to provide space for future cargo to be loaded elsewhere, etc. Finally, it is often the practice of loading personnel to utilize one of the larger boxes as the "pallet base" for equal size (length to length and width to width) and smaller boxes.

E. RELIANCE ON HEURISTICS

No reference could be found that presents an exact solution for the container stuffing problem. The complexity of the problem and need for rapid solutions exceed the capabilities of even the most sophisticated mathematical solutions currently available. Therefore, the solution techniques presented in this paper rely heavily on heuristics to approximate the exact solution to the stuffing problem.

II. OBJECTIVES AND SCOPE

The objective of this study was to develop a flexible algorithm capable of solving the above defined container stuffing problem. The algorithm which was developed presupposed that a computer would be required for the calculations and that all necessary data on the items to be loaded were available. These necessary items include dimensions of the box and its load bearing capabilities.

For tractability, each input box and the container was assumed to be a rectangular solid. This assumption as it related to the input boxes could be relaxed in actual practice by defining a rectangular solid which superscribes the object to be loaded and by designating this rectangular solid as a non-load bearing box. Likewise, the assumption of rectangularity of the shipping container can be relaxed by defining a rectangular solid which is superscribed by the actual container and by defining voids within this rectangular solid. The accuracy of this approximation is simply a function of the scaling of the dimensions used in the algorithm.

Weight distribution of items within the container was not explicitly addressed by the algorithm. Neither was center of gravity restrictions. However, these restrictions could be easily included by modification of peripheral logic in the algorithm.

III. THE STUFFING ALGORITHM

A. GENERAL DESCRIPTION

The stuffing algorithm (the FORTRAN program is contained in Appendix A) was designed to provide as much flexibility as possible, to be descriptive (i.e., describe the loading procedure in terms of relative positioning of each box) as well as prescriptive, and to run as fast as possible on a computer. As will be shown below, the amount of time required to execute the algorithm is a function of the options used as well as the level of optimization desired. By varying the input parameters the following options may be exercised:

(1) Prior to stuffing the container, the input boxes may be first loaded onto a "standard" pallet whose dimensions are specified by input parameters.

(2) Boxes larger than a certain size can be used as a base upon which to stack other boxes.

(3) Before loading a box the algorithm may or may not require that the box be supported at each of the box's lower four corners. If support is not required, boxes may "overhang" or even be suspended with no support as may be desired when, say, designing an electronic component comprised of many subcomponents which may be held in place by wiring.

(4) Boxes may be individually specified as non-load bearing boxes which denies their use as support for other boxes. Non-load bearing boxes may still be overstacked

provided the overstacked box receives support from load bearing boxes.

(5) The container is initially defined to be a rectangular solid with rectangular solids (i.e., voids) cut from the original rectangular solid. Thus, any reasonable geometric shape may be approximated.

(6) Voids may be described either in pallets or in the container or both, provided the voids can be constructed of a series of rectangular solids. The void need not be contiguous to a boundary of the pallet or the container.

(7) Voids placed in pallets and/or containers may either be load bearing or non-load bearing.

(8) Boxes may be rotated from zero to five times in order to improve local optimization of the loading process.

(9) Boxes may be specified whereby no other box is allowed contiguous to one of the specified box's five remaining sides.

(10) The level of optimization, and, therefore, the amount of computer time is specified by input parameters.

(11) The algorithm may be used to load either three, two, or one dimensional objects (rectangular solids, rectangles, or lines).

B. MEASURE OF EFFECTIVENESS

The measure of effectiveness (MOE) used in the optimization sequence was defined as the total volume of input boxes divided by the volume of the containers into which the boxes were stuffed. The volume of the containers was defined as:

$$(N-1)(VOL) + (MAXW \div CONW)(VOL) ,$$

where: N = Number of containers utilized

VOL = Volume of one container

MAXW = Maximum width utilized in the last container

CONW = Container width

This measure of effectiveness was devised in order to penalize for any wasted volume on pallets as well as wasted volume in the container itself and to allow differentiation between various loading sequences for the case in which all boxes were stuffed into one container.

As an example, the measure of effectiveness for the example problem solved in Chapter IV in Figure 3, is 0.733 and is computed as follows.

Total box volume is 228,096, container dimensions and volume are 60x60x96 and 345,600, respectively, and all boxes were stuffed into one container.

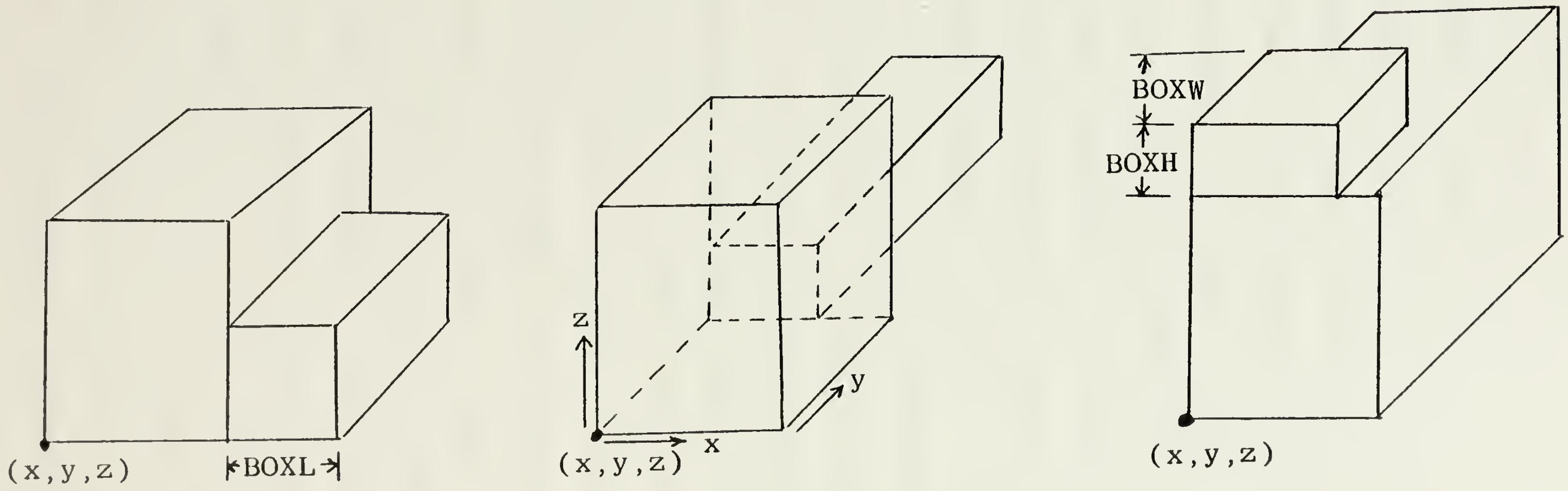
The formula shown above then gives:

$$MOE = (228{,}096)\div((1-1)(345{,}600)+(54\div 60)(345{,}600))=0.733.$$

C. PREVIEW OF THE ALGORITHM

Before discussing the algorithm in detail, it is first necessary to describe the general approach to the stuffing algorithm and to set forth a few basic definitions.

The algorithm loads one "pallet" (as defined below) at a time by inspecting each of the n boxes in the ordered input stream of boxes. Box number one is inspected first,



x-position y-position z-position

Figure 3. Possible Origins for Placing Additional Boxes on the Pallet.

box number two is inspected second, and so forth until all n boxes have been inspected. If the box under inspection can be loaded without violation of one of the conditions (constraints) discussed in Section IIIA above, the box is loaded. If the current box does violate one of the constraints, it is passed over and the next box in the sequence is inspected. If none of the boxes waiting to be loaded can be loaded, a new pallet is begun. Thus, the algorithm maintains "feasibility" while searching for one particular solution (i.e., a local minimum) to the stuffing problem.

The loading procedure requires a decision to be made as to where an additional box may be placed. These locations (defined as "possible" origins) are limited by the algorithm to be the origin of the pallet or one of three positions relative to each of the boxes and voids previously loaded on the pallet as measured from the origin of the pallet. These positions are defined as the "x-position", "y-position", and "z-position" and are shown in Figure 3. The dimensions of the box being added are denoted by BOXL, BOXW, and BOXH corresponding to its length, width and height, respectively. A pallet which contains j boxes and voids will have (3j+1) possible origins. These positions were selected as possible origins because they limit the possible positions of the next box to a finite, manageable number of locations and a fast verification of feasibility. Finally, of all the "possible" origins, a subset of "permissible" origins is defined. This subset of "permissible" origins

is determined by deleting from all possible origins those origins which have already been utilized by loaded boxes; by deleting the z-positions of all boxes defined to be non-load bearing boxes; by deleting positions at which none of the boxes still in the input stream can possibly fit; and by deleting positions at which it is desired to have no boxes contiguous to a loaded box's face (for example, if it be desired to have no box to the right (y-direction) of a given box, the y-position associated with the given box would not be included in the set of permissible origins.

The order of inspection of those permissible origins is (1) the x-position ordered from the first loaded box to the last loaded box; (2) the y-position similarly ordered; (3) lastly the z-position likewise ordered from the first to the last loaded box. This order of inspection tends to fill the pallet in layers, always starting from the pallet's origin and progressing away from the origin in all directions.

In order to determine if a box may be loaded at a given permissible origin, it is necessary to maintain a record of all previously loaded boxes and their relative positions in the pallet. This is accomplished by maintaining a record of the previously loaded boxes' origins (defined as the "current" origins) and the boxes' dimensions in the x, y, and z directions. Thus, the first part of the feasibility question is answered by considering the box at a particular permissible origin and determining if the box is wholly contained within the space of the pallet and if the box does not intersect any previously loaded box or void.

The second part of the feasibility question must be addressed whenever the problem input parameters require that each box must be supported. A box is considered to be supported whenever all four of its lower corners rest upon a load-bearing box or void. This requirement, when exercised, does not allow any "overhang" of the box.

A local minimum is obtained by attempting to move each box, as it is loaded, toward the origin of the pallet. This is accomplished by determining if the box may be moved along one of the three directions, x, y or z, toward the pallet's origin. Movement is permitted only if the box does not intersect any previously loaded box or defined void. The box is moved in one direction at a time and movement is continued in an iterative fashion until no further movement toward the origin is possible.

Finally, the term "pallet" is formally defined as a volume in which boxes are loaded. A "pallet" has dimensions of length, width, and maximum stacking height. A "pallet" does not, itself, occupy space. The dimensions of the pallet are determined by the input parameters. In the algorithm, two types of pallets are used; a "standard" pallet and a "minimum" pallet. The "minimum" pallet actually defines the smallest sized box which will be allowed to serve as a pallet base. The algorithm operates by selecting the next box in the input stream of boxes which is outsized to the minimum pallet. The dimensions of this box are then used to define the pallet base upon which to stack subsequent boxes. If no box is outsized

to the minimum pallet, the standard pallet is then used as the pallet upon which to stack boxes. A box is outsized if either the length of the box is larger than the length of the minimum or the width of the box is larger than the width of the minimum pallet. Thus, if prior palletization is not desired, the minimum pallet and the standard pallet are defined to be the same size as the container. Conversely, if it be desired to use the boxes themselves entirely to palletize the remaining boxes, the minimum pallet dimensions are defined to be zero.

In order to clearly present the algorithm, the next section will briefly describe the notation used in the stuffing algorithm. Following this section, the algorithm will be stated. After the statement of the algorithm, a brief, sample problem will be solved for illustration purposes.

D. NOTATION AND DESCRIPTION OF MATRICES

Before setting forth the exact stuffing algorithm, notation will be briefly covered and the matrices used in the algorithm will be defined.

There are n boxes to be loaded and their characteristics are contained in a matrix C. The original identification of an individual box is denoted as N. The subscript which refers to the order in the input sequence of box N is θ. Matrix C is formally defined as the (px5) matrix of input boxes as follows:

$$C = \begin{pmatrix} N_1 & r_1 & BOXL_1 & BOXW_1 & BOXH_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ N_p & r_p & BOXL_p & BOXW_p & BOXH_p \end{pmatrix}$$

where: N_θ = box identification of BOX_θ, $1 \leq \theta \leq p$

r_θ = number of boxes with dimensions of $(BOXL_\theta \times BOXW_\theta \times BOXH_\theta)$.

Since there are n input boxes, $\sum_\theta r_\theta = n$. Matrix C is used in the algorithm as a device to maintain a record of boxes yet to be loaded.

The subscript which refers to the order in which box N is loaded onto the pallet is j. Thus N_{θ_j} represents the completed notation for box ordering. By $N_{\theta_j} = 2_{5_3}$ is meant that a box with identification number two was the fifth box in the ordered input stream and was the third box to be loaded. The voids, V, which may be defined on the pallets and the container are subscripted with an i. Thus $V_i = V_1$ could represent void one on the pallet currently being loaded whose dimensions are length, width, and height of $VL_i = VL_1$, $VW_i = VW_1$ and $VH_i = VH_1$, respectively.

In order to permit a very rapid determination of whether a given box will fit at a given origin, a digital model of the pallet is established and updated with each box which is loaded onto the pallet. This digital model allows the determination of fit to be made through a series of very fast logic checks as described in the next section. This

model is defined as Array A which is an $((m+n)x7)$ matrix as follows:

$$A = \begin{pmatrix} 1 & x_1 & y_1 & z_1 & (x_1+VL_1) & (y_1+VW_1) & (z_1+VH_1) \\ 2 & x_2 & y_2 & z_2 & (x_2+VL_2) & (y_2+VW_2) & (z_2+VH_2) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ m & x_m & y_m & z_m & (x_m+VL_m) & (y_m+VW_m) & (z_m+VH_m) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ N_{\theta_{m+j}} & x_{\theta_{m+j}} & y_{\theta_{m+j}} & z_{\theta_{m+j}} & (x_{\theta_{m+j}}+BOXL_{\theta_{m+j}}) & (y_{\theta_{m+j}}+BOXW_{\theta_{m+j}}) & (z_{\theta_{m+j}}+BOXH_{\theta_{m+j}}) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{pmatrix}$$

where: x_i, y_i, z_i are the coordinates of the $i^{\underline{th}}$ void whose length, width and height are VL_i, VW_i, and VH_i, respectively, $0 \leq i \leq m$.

N_{θ_j} is the identification number of BOX_θ whose length, width and height are $BOXL_\theta$, $BOXW_\theta$, $BOXH_\theta$, $1 \leq \theta \leq n$, $1 \leq j \leq n$, and whose origin is located at coordinates $(x_{\theta_j}, y_{\theta_j}, z_{\theta_j})$.

Thus, matrix A column one identifies the box (or void), columns two through four identify the box's (or void's) location nearest the pallet origin, and columns five through seven in conjunction with columns two through four describe the volume occupied by the box (or void).

To facilitate the selection of the next origin at which the algorithm will attempt to load the current box, a logical array of possible and permissible origins is established. By an extremely rapid scan of this model, defined as matrix B,

the next origin is quickly determined. Matrix B is an ((m+n)x3) matrix as follows:

$$B = \begin{pmatrix} XORG_1 & YORG_1 & ZORG_1 \\ \vdots & \vdots & \vdots \\ XORG_m & YORG_m & ZORG_m \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ XORG_{\theta_{m+j}} & YORG_{\theta_{m+j}} & ZORG_{\theta_{m+j}} \\ \vdots & \vdots & \vdots \end{pmatrix}$$

where: $XORG_i$, $YORG_i$, $ZORG_i$, $0 \leq i \leq m$, are logical variables which when true indicate that $((x_i + VL_i, y_i); (x_i, (y_i + VW_i), z_i);$ and $(x_i, y_i, (z_i + VH_i)),$ respectively are permissible origins next to voids and $XORG_{\theta_j}$, $YORG_{\theta_j}$, $ZORG_{\theta_j}$, $1 \leq j \leq n$, are logical variables which when true indicate that $((x_{\theta_j} + BOXL_{\theta_j}, y_{\theta_j}, z_{\theta_j}); (x_{\theta_j}, (y_{\theta_j} + BOXW_{\theta_j}), z_{\theta_j});$ and $(x_{\theta_j}, y_{\theta_j}, (z_{\theta_j} + BOXH_{\theta_j})),$ respectively are permissible origins next to loaded boxes. For ease of notation, once a permissible origin has been selected for inspection, it will be designated merely as (ORX, ORY, ORZ).

Each row of matrix B corresponds to a row in matrix A. The three elements in each row of matrix B correspond to the x-direction, y-direction and z-direction possible origins associated with each void and box on the current pallet (and described by matrix A). Of all the possible origins, the permissible origins are then defined by setting to a true value each element in matrix B which corresponds to the possible origin which is also a permissible origin. It is

precisely these permissible origins where attempts will be made to load additional boxes.

E. EXACT STATEMENT OF THE STUFFING ALGORITHM

To stuff n boxes (which are described by matrix C) into containers the following steps are used.

1. Select the first ordered box which is outsized to the "minimum" pallet dimensions. Define the pallet base as this outsized box. If no outsized box is found, define the pallet as the standard pallet.

2. Establish matrix A as the digital model of the pallet.

3. Establish matrix B as the logical model of possible and permissible origins.

4. Load the outsized box if one were found. Otherwise, load the first box from matrix C. Augment matrices A and B with an additional row to represent this box. Adjust matrix B as necessary to remove, if necessary, an origin from the set of permissible origins.

5. Select the next box in matrix C. If no more boxes are left, go to step 12.

6. Select the next permissible origin. The next permissible origin corresponds to the next true element in column 1 of matrix B (x-position), followed by the next true element in the second column of matrix B (y-position), and finally followed by the next true element in the third column of matrix B (z-position). Call the selected origin (ORX, ORY, ORZ). If all origins have been tried and the box may

be rotated, go to step 11. If all positions have been tried and the box may not be rotated go to step 5.

7A. Determine if the box will fit at this origin. If it will not fit go to step 6 (The method of this determination will be described below).

7B. Improve the density of packing, if possible (This procedure will also be described below).

8. If boxes must be supported (as discussed above), determine if the box is supported (as discussed below). If the box must be supported but is not supported, go to step 6.

9. Load the box and augment matrices A and B with an additional row. Adjust matrix B to preclude any origin that may not be used.

10. Go to step 5.

11. Turn the box and go to step 6.

12. If all boxes in matrix C are not yet loaded, go to step 5. If all boxes are loaded and the container has been stuffed, terminate the algorithm. If all boxes are loaded onto pallets but the pallets have not been stuffed into containers, move the pallets into array C, define the minimum and standard pallets as the container dimensions, and repeat the algorithm by returning to step 1.

Step 7A is determined as follows. Inspect each previously loaded BOX_{θ_j}, $m+1 \leq j < m+n-1$ and reject the loading of the current box BOX_{θ_k} because it would intersect BOX_{θ_j} if

$A(j,2) < (ORX + BOXL_{\theta_k})$ and $A(j,5) > ORX$ and

$A(j,3) < (ORY + BOXW_{\theta_k})$ and $A(j,6) > ORY$ and

$A(j,4) < (ORZ + BOXH_{\theta_k})$ and $A(j,7) > ORZ$

where: A(j,k) is an element in matrix A and (ORX, ORY, ORZ) is the origin being inspected.

If voids (V) were introduced, a similar inspection would be necessary of each V_i, $0 \leq i \leq m$ whereby VL_i, VW_i, and VH_i would be substituted for $BOXL_{\theta_j}$, $BOXW_{\theta_j}$, and $BOXH_{\theta_j}$, respectively.

Step 7B is determined as follows. Inspect, one at a time, each possible direction of improvement (x, y, z). Each direction of improvement is found by inspecting the origin (ORX, ORY, ORZ) under question and each row of matrix A. To determine if improvement be possible in the x direction, the following logic check is made on each row, k, of matrix A:

$$A(j,2) > (ORX+BOXL_{\theta_k}) \text{ or } A(j,3) > (ORY+BOXW_{\theta_k}) \text{ or }$$
$$A(j,4) > (ORZ+BOXH_{\theta_k}) \text{ or } A(j,6) < ORY \text{ or }$$
$$A(j,7) < ORZ.$$

A true condition indicates that improvement is not possible at this row in matrix A. A false condition indicates that improvement is possible. The magnitude of improvement is: ORX - A(j,5) if improvement is possible or 99,999 if improvement is not possible. Now denote as $slack_k$ the magnitude of improvement found by inspecting row k of matrix A. The improvement found over all rows of matrix A is then:

$$\min(slack_1, \ldots, slack_{m+n}, ORX).$$

To determine improvement in the y direction the logic check is:

$A(j,3) > (ORY+BOXW_{\theta_k})$ or $A(j,2) > (ORX+BOXL_{\theta_k})$ or
$A(j,4) > (ORZ+BOXH_{\theta_k})$ or $A(j,5) < ORX$ or
$A(j,7) < ORZ$.

The magnitude of improvement when the logic check is false is $ORY - A(j,6)$.

To determine improvement in the z direction the logic check is:

$A(j,4) > (ORZ+BOXH_{\theta_k})$ or $A(j,2) > (ORX+BOXL_{\theta_k})$ or
$A(j,3) > (ORY+BOXW_{\theta_k})$ or $A(j,5) < ORX$ or
$A(j,6) < ORY$.

The magnitude of improvement when the logic check is false is $ORZ - A(j,7)$.

With each improvement, the origin (ORX, ORY, ORZ) of the box being loaded is adjusted. The search for improvement is continued until no improvement is found in any of the three dimensions.

Step 8 is determined as follows. Accept BOX_{θ_k} as supported if some BOX_{θ_j}, $m+1 \leq j \leq m+n-1$, for which $z_{\theta_j} + BOXH_{\theta_j} = z_{\theta_k}$, $m+1 < j < k \leq m+n$, and BOX_{θ_j} is not declared a non-load bearing box, satisfies the following condition:

$A(j,2) \leq xx_u$ and $A(j,5) \geq xx_u$ and
$A(j,3) \leq yy_u$ and $A(j,6) \geq yy_u$

for $u = 1,2,3,4$ where xx_u and yy_u are defined as follows:

When: $u = 1$ or 3 $\quad xx_u = x_{\theta_j}$

$u = 2$ or 4 $\quad xx_u = (x_{\theta_j} + BOXL_{\theta_k})$

$u = 1$ or 2 $\quad yy_u = y_{\theta_j}$

$u = 3$ or 4 $\quad yy_u = (y_{\theta_j} + BOXW_{\theta_k})$

Note the four (u) conditions are independently considered and one or more BOX_{θ_j} must be required to satisfy all these conditions. If load bearing voids were present, a similar inspection of V_i, $0 \leq i \leq m$, would be necessary.

F. SAMPLE TWO-DIMENSIONAL PROBLEM

In order to illustrate the algorithm, the following example is presented. It is a two dimensional problem since all features of the algorithm can be covered in two dimensions and two dimensions are more easily demonstrated. The three-dimensional stuffing algorithm is converted to a two-dimensional one by defining the height of each input box to be the height of the container, so that no stacking in the z direction occurs.

In this example problem, 4 boxes (of base sizes 30x30, 34x24, 20x20, and 26x10 and identification numbers 1 through 4 respectively) are to be loaded without standard pallets and without prior palletization into a container of 60(L) x 60(W) x 96(H) with one void (10x10) which is located in the lower right corner of the container. For illustration, this void may not have a contiguous box to its upper side. Each box may be rotated only once (i.e., all the boxes are marked "this side up"). The input stream of boxes has been ordered by area

(length times width). Since only two-dimensional loading is considered, the boxes' heights are defined to be the height of the container (i.e., 96). The minimum pallet and the standard pallet widths, lengths, and heights are 60, 60, and 96, respectively. Matrix C has elements as follows:

$$C = \begin{pmatrix} 1 & 1 & 30 & 30 & 96 \\ 2 & 1 & 24 & 34 & 96 \\ 3 & 1 & 20 & 20 & 96 \\ 4 & 1 & 26 & 10 & 96 \end{pmatrix}$$

Step 1. Select the first box outsized to the minimum pallet. There were none, so define the current pallet dimensions to be 60x60x96.

Step 2. Establish the A matrix which now contains all the voids (in this example there is only one). The A matrix, at this point is:

$$A = (1 \quad 50 \quad 0 \quad 0 \quad 60 \quad 10 \quad 96)$$

Step 3. Establish the B matrix of origins. Since the void has been specified so that no box may touch its upper face, its y-direction origin is not a permissible origin. The void also does not have a permissible x-direction origin nor z-direction permissible origin because no boxes yet to be loaded can fit at either of these origins inasmuch as the distance from these origins to a boundary of the pallet is zero. In fact, since all boxes have the same height as the pallet, B matrix will never show a permissible origin in the z-direction. Thus, B matrix is now:

$$B = (F \quad F \quad F)$$

Step 4. Load the next box in matrix C. This is box one which has dimensions of 30x30x96. Augment the A matrix to include this box as follows:

$$A = \begin{pmatrix} 1 & 50 & 0 & 0 & 60 & 10 & 96 \\ \\ 1 & 0 & 0 & 0 & 30 & 30 & 96 \end{pmatrix}$$

Augment B matrix and show permissible origins by setting the applicable element to true. Thus,

$$B = \begin{pmatrix} F & F & F \\ \\ T & T & F \end{pmatrix}$$

Step 5. Select the second box in the C matrix (24x34x96).

Step 6. Select the first permissible origin. That is, scan matrix B column by column always starting at the top of each column and working down. In this case, element B(2,1) is the next permissible origin. This element translates into an origin of (A(2,5), A(2,3), A(2,4)) or (30, 0, 0). Denote this as the current (ORX, ORY, ORZ).

Step 7. Determine if the box will fit at this origin. This is accomplished by the following logic checks of matrix A. A true condition for any row of matrix A indicates that the box will not fit. Thus for, say, row one the check proceeds as follows:

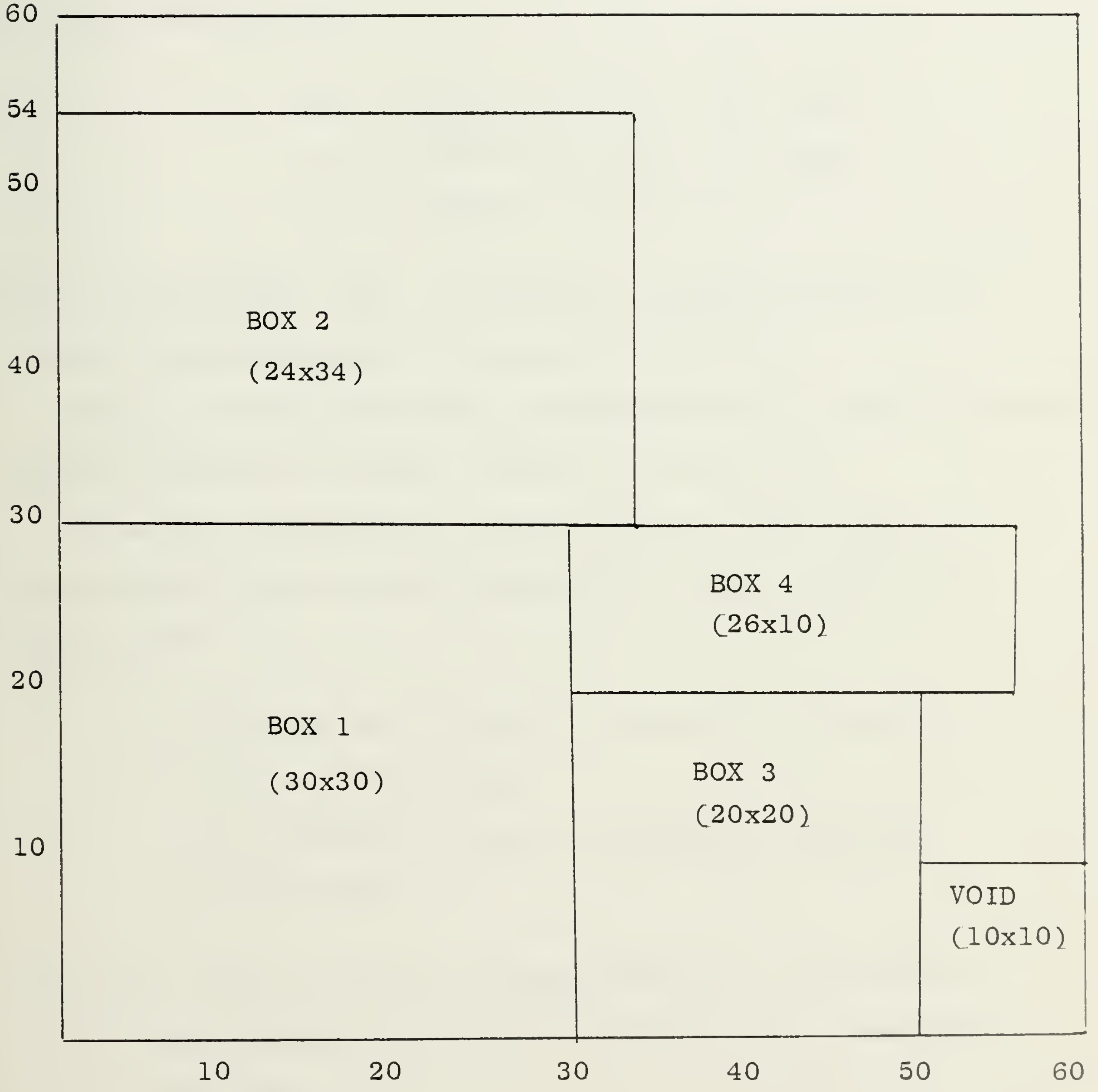


Figure 4. Example Problem.

$A(1,2) < (ORX+BOXL_{2_2})$ and $A(1,5) > ORX$ and

$A(1,3) < (ORY+BOXW_{2_2})$ and $A(1,6) > ORY$ and

$A(1,4) < (ORZ+BOXH_{2_2})$ and $A(1,7) > ORZ$

This equates to:

$$
\begin{array}{lll}
50 < (30+34) & \text{and} \quad 60 > 30 & \text{and} \\
0 < (\ 0+24) & \text{and} \quad 60 > \ 0 & \text{and} \\
0 < (\ 0+96) & \text{and} \quad 96 > \ 0 &
\end{array}
$$

which is obviously true. Therefore, the box will not fit at this origin because it intersects the void.

Step 6. Select the next permissible origin which is related to B(2,2) i.e.(A(2,2), A(2,6), A(2,4)) or (0, 30, 0).

Step 7A. Determine if box will fit at this origin. The following logic checks are made for rows one and two, respectively:

$$
\begin{array}{l}
50 < 34 \text{ and } 60 > 0 \text{ and } 0 < 54 \text{ and } 10 > 30 \text{ and} \\
\ 0 < 96 \text{ and } 96 > 0 \text{ and} \\
\ 0 < 34 \text{ and } 30 > 0 \text{ and } 0 < 54 \text{ and } 30 < 30 \text{ and} \\
\ 0 < 96 \text{ and } 96 > 0
\end{array}
$$

Since for rows one and two, respectively, $50 \nless 34$ and $30 \nless 30$, all logic checks are false and the box will, therefore, fit at this origin.

Step 7B. Improve the density of packing if possible. Since by simple inspection the box may not be moved toward the origin of the pallet, a detailed inspection will not be presented here. A detailed inspection will be given at a subsequent box.

Step 8. The second box is supported since the example deals with only two dimensions.

Step 9. Update matrices A and B which are now:

$$A = \begin{pmatrix} 1 & 50 & 0 & 0 & 60 & 10 & 96 \\ 1 & 0 & 0 & 0 & 30 & 30 & 96 \\ 2 & 0 & 0 & 0 & 34 & 54 & 96 \end{pmatrix}$$

$$B = \begin{pmatrix} F & F & F \\ T & F & F \\ T & F & F \end{pmatrix}$$

Step 5. Select box number 3 (20x20x96).

Step 6. Select origin (30,0,0), B=(2,1).

Step 7. Box will fit and improvement is not possible.

Step 8. This box is supported.

Step 9. Adjust A and B matrices as follows:

$$A = \begin{pmatrix} 1 & 50 & 0 & 0 & 60 & 10 & 96 \\ 1 & 0 & 0 & 0 & 30 & 30 & 96 \\ 2 & 0 & 30 & 0 & 34 & 54 & 96 \\ 3 & 30 & 0 & 0 & 50 & 20 & 96 \end{pmatrix}$$

$$B = \begin{pmatrix} F & F & F \\ F & F & F \\ T & F & F \\ F & T & F \end{pmatrix}$$

Step 5. Select box 4 (26x10).

Step 6. Select origin (34,30,0), B=(3,1).

Step 7A. Box will fit.

Step 7B. Improve density. Inspect each row of matrix A for an improving direction in the x, y, and z directions. For illustration, the improvement in the y direction will be shown. It is first necessary to find the row of matrix A in which the following relationship does not hold (as discussed in Section IIIE above). Note the origin is (ORX, ORY, ORZ) = (34,30,0) and that the box dimensions are ($BOXL_{4_4}$, $BOXW_{4_4}$, $BOXH_{4_4}$) = (26x10x96).

For illustration, the inspection of row four of matrix A is shown. This corresponds to box number 3.

$A(4,2) > (34+26)$ or $A(4,3) > 30$ or $A(4,4) > 96$ or
$A(4,5) < 34$ or $A(4,7) < 0$ or $A(4,6) < 30$.

This results in: $30 > 60$ or $0 > 30$ or $0 > 96$ or
$50 < 34$ or $96 < 0$ or $20 < 30$

Since the last term ($20 < 30$) is true, improvement in the y direction is possible. This improvement is 30-20 = 10. Therefore, the origin of the box is now defined to be (34,20,0). A similar inspection in the x direction would show an improvement of 4 units, making the final origin (30,20,0).

Step 8. Box is supported.

Step 9. Update matrices A and B as follows:

$$A = \begin{pmatrix} 1 & 50 & 0 & 0 & 60 & 10 & 96 \\ 1 & 0 & 0 & 0 & 30 & 30 & 96 \\ 2 & 0 & 30 & 0 & 34 & 54 & 96 \\ 3 & 30 & 0 & 0 & 50 & 20 & 96 \\ 4 & 30 & 20 & 0 & 56 & 30 & 96 \end{pmatrix}$$

Matrix A now shows the pallet as it was loaded. Column one gives the identification number of the box, columns two, three and four give the origin of the box, and columns five, six and seven give the orientation of the box.

Figure 4 shows the result of the above example.

G. OPTIMIZATION

In order to move from a local optimum toward the global optimum the following branching search can be made as suggested by Stoyan [4]:

Step 1. An initial sequence A_o of the boxes BOX_i, i = (1,n), is chosen, the boxes are palletized, and the pallets are loaded in the container.

Step 2. Using a uniform (1,n) pseudorandum number generator, s random numbers are generated (s<<n) and the boxes with these s indexes are shuffled.

Step 3. The new sequence is loaded and the efficiency of the new local optimum is measured. If the efficiency improved go to step number 2.

Step 4. Replace the sequence as it existed prior to the shuffle and go to step 2.

The above algorithm is repeated until either a predetermined amount of time is consumed or a predetermined efficiency is reached.

H. OBTAINING A BETTER INITIAL SOLUTION

Several approaches were found useful in obtaining a better initial solution. These included defining the input sequence of the boxes to be loaded according to a preconceived routine, selecting an optimal maximum number of turns of the input boxes, and sorting the pallets prior to stuffing the pallets into the container. These approaches are discussed at the end of the next chapter.

IV. VERIFICATION

A. RELATED ALGORITHMS

Because the problems solved by Galata and Stoyan [4] and by DeSha [2] are subsets of the stuffing problem, verification of the current stuffing algorithm was possible by (a) solving the same example as presented by Galata and Stoyan and (b) by using DeSha's FORTRAN program to solve a problem which had been also solved by the stuffing algorithm.

A solution to the minimization example of Galata and Stoyan was obtained by the stuffing algorithm in 0.9 seconds with a minimum value of $z = 23.2$ as opposed to the original solution of $z = 24.5$ obtained by 540 searches which took approximately 31 seconds each. According to reference 4, in their problem Galata and Stoyan loaded 95 rectangular solid items onto a base with the objective of minimizing the height, z, which was needed in order to fit all 95 solids onto the base. In their problem, boxes need not be supported.

The FORTRAN program given by DeSha was used to solve the sample data discussed below: DeSha's solution showed a 86.9% volume efficiency and an area efficiency of 92%. The stuffing algorithm showed an 89.1% volume efficiency and a 95% area efficiency.

B. SAMPLE DATA

In order to fully test the stuffing algorithm, actual data were collected at Naval Supply Center, Oakland, California, Navy Exchange Retail Distribution Center in December 1978. These data, as shown in table I, were gathered by individually measuring boxes which were actually loaded (stuffed) into an eight-foot by eight-foot by forty-foot shipping container. The container was loaded in six hours by two men who utilized one forklift truck. The men were asked to load the container as efficiently as possible in order to measure their abilities against simulated stuffing by a computer program. The cargo was not palletized externally to the container but pallets were used implicitly in the container. The pallets consisted of larger boxes placed on the floor of the container upon which smaller boxes were stacked. All boxes which were loaded were load-bearing boxes, and weight and center of gravity considerations were not addressed by the loading crew. Actual effectiveness achieved by the loading crew was 87% as compared to reported Naval Supply Center, Oakland averages of 90% for Navy Exchange cargo and 80% for general cargo (which consists of repair parts, equipment, and general consumable supplies).

C. SAMPLE DATA RESULTS

The above sample data were utilized to test the stuffing algorithm utilizing various ordering of the input stream of boxes and various number of turns allowed. Table II gives

the results of a nine by seven factorial experiment layout. During this experiment, pallets were defined to be the next box in the ordered input stream of boxes to be loaded. Each cell of table II gives the numbers of pallets necessary to stack all boxes, the IBM 360 computer run time in seconds necessary to load the boxes onto pallets and to stuff the pallets into containers, and the percent volumetric efficiency realized. Table III performs the same experiment except pallets were defined to be a standard pallet (40 inch by 44 inch) if the next box in the input stream of boxes could be contained in this standard pallet. If the box could not be contained, the pallet was defined to be the box itself.

Sample output of the FORTRAN program is presented in tables IV through VII for the test case in which standard pallets were not utilized and the input stream of boxes was ordered (highest to lowest) according to the boxes' base perimeter (sort control 4 as defined in the FORTRAN program) shown in the Computer Program section below. Table IV shows the boxes after they were ordered, table V shows the first pallet which was stacked, table VI presents a summary of all pallets which were stacked, and table VII shows the results of stuffing the pallets into the container.

Similar results are shown in tables VIII through XI for the test case in which standard pallets were utilized and the input stream of boxes was ordered according to the boxes' height.

D. ANALYSIS OF VARIANCE

An analysis of variance of tables II and III was performed in order to determine if a difference in efficiency of loading existed due to different methods of sorts and due to different number of turns allowed of the box. A level of significance of $\alpha = .10$ was chosen. These analyses showed that for the case in which standard pallets were not utilized, there was a significance between the type of sort utilized and there was a difference between the number of turns allowed. (The F statistic for these tests was, respectively, $F_{(6,48)} = 3.78$ and $F_{(8,48)} = 57.9$.) These analyses for the case in which standard pallets were utilized showed there was a difference in the number of turns allowed ($F_{(6,48)} = 1.97$) and that there was a difference in the type of sort utilized ($F_{(8,48)} = 3.91$).

Although the data in tables II and III indicate that strong interaction may exist between the number of turns allowed and the type of sort utilized, the lack of replications of the experiment due to the existence of only one set of data make the existence of possible interaction impossible to verify.

E. RANGE TEST AND CONFIDENCE LIMITS

In order to determine which type of sorts in tables II and III and which number of turns in table II and table III produced the highest efficiences, Newman-Keuls range tests [13] were performed. The results of these tests are shown

in tables XII and XIII in which an 'x' indicates a difference in the means and an '0' indicates no difference in the means. Of course, the range test was performed at the level of significance of $\alpha = .10$.

Tables XII and XIII also give 90-percent confidence limits on the means listed therein.

F. DISCUSSION OF TECHNIQUES TO IMPROVE SOLUTIONS

Table XII shows that the greatest efficiencies when loading boxes without standard pallets occurs when boxes are sorted by area prior to their stacking. Stoyan's procedure [4], discussed in Chapter V, was then applied in an attempt to improve on that solution. No improvements were found in 97 separate trials with four pairs of boxes interchanged on each trial. These trials tend to confirm that for the specific data available and for the specific method selected to load the boxes, the area ordering represents the best initial local optimum for the stuffing algorithm (when loading boxes without standard pallets). A similar test was conducted in the case where standard pallets were utilized. In this test 10 separate trials were conducted during which no improvement was found.

V. CONCLUSIONS AND RECOMMENDATIONS

The stuffing algorithm presented in this paper has demonstrated the possibility of achieving slightly better "loading" performance than is usually obtainable by experienced loading personnel. However, its major advantages may be in its ability to allow reasonably accurate predictions of container requirements and in the increased speed with which a container may be loaded because the loading personnel have a plan to follow.

This type of algorithm may be capable of allowing the full potential of mechanized warehouses to be realized by allowing the shipping department to "call forth" issues from the storage department when transportation assets are available. This would allow issue documents to accumulate in the mechanized warehouse's computerized data system as opposed to accumulating the issued material on the shipping dock.

Additional data are required to verify or disprove the results presented in this study and to determine the existence of the suspected interaction in the analysis of variance for the sorting of the boxes and the effects of the number of turns allowed.

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
1.000	4.000	14.000	10.000	8.000
2.000	2.000	20.000	15.000	8.000
3.000	1.000	27.000	27.000	7.000
4.000	20.000	10.000	8.000	9.000
5.000	14.000	12.000	8.000	6.000
6.000	6.000	12.000	9.000	7.000
7.000	6.000	9.000	9.000	6.000
8.000	4.000	25.000	25.000	8.000
9.000	3.000	34.000	26.000	5.000
10.000	1.000	21.000	14.000	12.000
11.000	1.000	46.000	26.000	30.000
12.000	1.000	12.000	9.000	9.000
13.000	2.000	26.000	16.000	18.000
14.000	4.000	25.000	20.000	27.000
15.000	11.000	12.000	10.000	10.000
16.000	4.000	13.000	12.000	10.000
17.000	1.000	16.000	15.000	12.000
18.000	1.000	26.000	16.000	15.000
19.000	7.000	23.000	23.000	30.000
20.000	1.000	24.000	24.000	35.000
21.000	1.000	12.000	12.000	15.000
22.000	50.000	13.000	13.000	12.000
23.000	8.000	18.000	18.000	8.000
24.000	12.000	19.000	8.000	9.000
25.000	6.000	9.000	8.000	6.000
26.000	8.000	7.000	6.000	4.000
27.000	42.000	9.000	8.000	9.000
28.000	2.000	16.000	11.000	18.000
29.000	4.000	18.000	12.000	8.000
30.000	4.000	16.000	10.000	8.000
31.000	1.000	26.000	20.000	28.000
32.000	2.000	13.000	10.000	7.000
33.000	2.000	18.000	10.000	8.000
34.000	4.000	15.000	10.000	8.000
35.000	5.000	21.000	14.000	7.000
36.000	7.000	16.000	12.000	8.000
37.000	6.000	12.000	6.000	8.000
38.000	12.000	12.000	9.000	8.000
39.000	24.000	12.000	10.000	8.000
40.000	2.000	11.000	10.000	7.000
41.000	3.000	12.000	12.000	7.000
42.000	4.000	9.000	7.000	6.000
43.000	5.000	11.000	8.000	8.000
44.000	18.000	16.000	11.000	6.000
45.000	1.000	13.000	12.000	13.000
46.000	2.000	20.000	16.000	21.000
47.000	1.000	20.000	15.000	31.000
48.000	2.000	29.000	20.000	31.000
49.000	14.000	22.000	9.000	10.000
50.000	1.000	47.000	26.000	15.000
51.000	2.000	65.000	21.000	19.000
52.000	1.000	12.000	12.000	13.000
53.000	4.000	18.000	13.000	14.000
54.000	3.000	57.000	11.000	10.000
55.000	5.000	60.000	10.000	6.000
56.000	3.000	13.000	7.000	6.000
57.000	2.000	15.000	8.000	8.000
58.000	8.000	12.000	8.000	9.000
59.000	1.000	35.000	25.000	5.000
60.000	12.000	27.000	20.000	18.000
61.000	18.000	8.000	8.000	6.000
62.000	26.000	10.000	6.000	6.000
63.000	10.000	12.000	8.000	8.000

SAMPLE DATA

TABLE I

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
64.000	12.000	9.000	6.000	8.000
65.000	1.000	32.000	18.000	22.000
66.000	1.000	32.000	18.000	15.000
67.000	1.000	32.000	18.000	20.000
68.000	2.000	25.000	23.000	15.000
69.000	1.000	25.000	25.000	16.000
70.000	1.000	25.000	23.000	23.000
71.000	1.000	35.000	23.000	24.000
72.000	1.000	46.000	40.000	20.000
73.000	1.000	46.000	44.000	34.000
74.000	3.000	10.000	8.000	6.000
75.000	14.000	12.000	9.000	6.000
76.000	24.000	14.000	6.000	16.000
77.000	3.000	20.000	14.000	12.000
78.000	1.000	47.000	40.000	43.000
79.000	2.000	24.000	19.000	15.000
80.000	2.000	24.000	19.000	13.000
81.000	1.000	43.000	36.000	51.000
82.000	1.000	24.000	18.000	29.000
83.000	1.000	43.000	43.000	46.000
84.000	2.000	26.000	15.000	17.000
85.000	1.000	24.000	16.000	10.000
86.000	1.000	48.000	40.000	62.000
87.000	1.000	27.000	24.000	18.000
88.000	1.000	36.000	24.000	28.000
89.000	1.000	12.000	12.000	16.000
90.000	2.000	11.000	8.000	10.000
91.000	4.000	8.000	7.000	8.000
92.000	10.000	8.000	7.000	6.000
93.000	1.000	24.000	19.000	32.000
94.000	4.000	13.000	8.000	8.000
95.000	12.000	12.000	11.000	9.000
96.000	7.000	12.000	10.000	8.000
97.000	3.000	20.000	6.000	8.000
98.000	158.000	18.000	12.000	7.000
99.000	1.000	52.000	44.000	48.000
100.000	1.000	50.000	42.000	39.000
101.000	1.000	49.000	42.000	38.000
102.000	1.000	48.000	40.000	72.000
103.000	3.000	13.000	10.000	12.000
104.000	1.000	48.000	42.000	40.000
105.000	1.000	48.000	42.000	26.000
106.000	2.000	20.000	11.000	10.000
107.000	16.000	22.000	6.000	9.000
108.000	8.000	12.000	8.000	18.000
109.000	8.000	12.000	8.000	13.000
110.000	8.000	12.000	9.000	14.000
111.000	12.000	12.000	9.000	5.000
112.000	6.000	18.000	14.000	6.000
113.000	1.000	14.000	11.000	10.000
114.000	25.000	23.000	9.000	10.000
115.000	2.000	20.000	12.000	14.000
116.000	1.000	21.000	16.000	19.000
117.000	17.000	12.000	8.000	5.000
118.000	3.000	14.000	14.000	8.000
119.000	60.000	8.000	6.000	8.000
120.000	1.000	50.000	22.000	8.000
121.000	2.000	16.000	14.000	9.000
122.000	16.000	8.000	6.000	5.000
123.000	20.000	9.000	6.000	5.000
124.000	3.000	16.000	14.000	22.000
125.000	20.000	12.000	8.000	7.000
126.000	1.000	23.000	14.000	15.000
127.000	4.000	26.000	22.000	14.000

SAMPLE DATA

TABLE I (CONTINUED)

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
128.000	2.000	13.000	8.000	10.000
129.000	5.000	10.000	8.000	8.000
130.000	3.000	24.000	16.000	20.000
131.000	60.000	10.000	10.000	8.000
132.000	2.000	8.000	8.000	8.000
133.000	10.000	13.000	9.000	4.000
134.000	3.000	10.000	9.000	11.000
135.000	3.000	18.000	12.000	9.000
136.000	1.000	11.000	11.000	10.000
137.000	1.000	20.000	16.000	17.000
138.000	2.000	22.000	19.000	15.000
139.000	3.000	20.000	19.000	10.000
140.000	2.000	15.000	10.000	12.000
141.000	1.000	17.000	12.000	14.000
142.000	2.000	20.000	13.000	16.000
143.000	3.000	16.000	16.000	5.000
144.000	1.000	26.000	18.000	16.000
145.000	6.000	9.000	8.000	7.000
146.000	14.000	10.000	7.000	7.000
147.000	4.000	12.000	10.000	10.000
148.000	9.000	18.000	12.000	6.000
149.000	2.000	14.000	8.000	10.000
150.000	27.000	16.000	16.000	16.000
151.000	69.000	18.000	16.000	14.000
152.000	80.000	19.000	12.000	7.000
153.000	1.000	48.000	42.000	4.000
154.000	12.000	15.000	14.000	14.000
155.000	27.000	9.000	7.000	7.000

SAMPLE DATA

TABLE I (CONTINUED)

	NUMBER OF TURNS OF BOX ALLOWED							
TYPE SORT (input)	0	1	2	3	4	5	6	Mean
No Sort (0)	81 40.7 72.87	88 79.0 73.00	88 68.3 73.14	93 102.2 75.12	93 105.2 74.4	88 139.9 78.15	88 137.5 78.15	88 96.1 74.98
Height (1)	91 30.5 82.65	97 50.6 73.70	97 49.5 73.70	95 89.7 79.11	95 84.7 81.10	96 119.1 81.27	96 113.1 85.01	95 76.7 79.51
Length (2)	117 13.3 85.95	118 21.6 86.14	118 22.1 86.53	126 29.6 84.82	126 28.3 84.82	124 44.2 86.33	124 41.3 85.01	122 28.6 85.65
Width (3)	111 13.2 85.20	111 24.5 85.01	111 23.8 84.45	115 36.4 85.20	115 34.2 85.20	120 56.3 86.33	120 51.9 85.76	115 34.3 85.31
Area (4)	125 7.6 88.50	124 11.6 89.11	124 11.3 89.11	128 19.3 85.57	128 19.2 85.76	129 23.9 86.14	129 25.5 86.33	127 16.9 87.22
Volume (5)	103 16.4 8.144	97 45.1 81.95	97 43.3 83.01	126 24.4 84.45	126 24.3 84.45	128 28.0 86.72	128 27.0 86.72	116 29.8 84.11
Total Volume (6)	74 69.0 72.87	72 121.7 72.87	72 119.8 73.98	79 191.5 78.15	79 188.0 78.63	80 320.0 75.42	80 344.3 75.42	77 193.5 75.33
Random (7)	73 89.7 67.18	66 129.5 70.23	66 127.3 70.23	73 24.79 73.56	73 14.0 73.00	69 341.9 72.87	69 342.0 72.87	70 184.6 71.42
Number Boxes (8)	123 8.4 70.48	123 11.6 70.22	123 11.3 70.48	123 26.5 73.48	123 25.7 73.14	121 36.7 77.22	121 36.9 77.22	123 22.4 73.14
Mean	100 32.1 78.57	100 55.0 78.03	100 53.0 78.29	106 85.3 79.94	106 58.2 80.06	106 123.3 81.16	106 124.4 81.39	103 75.8 79.63

CASE 1: Standard Pallets Not Used
Number of Pallets/Time to Stack Pallets (secs)/Total % Volume Efficiency

TABLE II

TYPE SORT (input)	NUMBER OF TURNS OF BOX ALLOWED							
	0	1	2	3	4	5	6	Mean
No Sort (0)	38 135.9 49.26	36 227.6 52.17	36 227.8 52.17	35 334.2 55.46	35 334.2 55.46	35 498.8 55.46	35 499.0 55.46	36 322.5 53.68
Height (1)	38 93.8 52.10	37 153.7 55.38	37 153.9 52.17	34 275.8 59.09	34 276.0 59.18	32 380.0 62.93	32 380.0 63.34	35 244.7 57.74
Length (2)	30 105.7 55.46	32 267.5 52.17	32 267.8 52.17	33 520.1 52.10	33 520.1 52.10	32 685.1 52.17	32 685.1 52.17	32 435.9 52.62
Width (3)	35 92.4 55.46	34 125.4 59.09	34 125.5 59.09	37 406.0 55.46	37 406.1 55.46	37 609.5 55.46	37 609.6 55.46	36 339.2 56.50
Area (4)	31 158.0 55.38	30 295.4 55.46	30 295.5 55.46	30 505.9 55.38	30 505.9 55.38	30 784.3 55.38	30 784.4 55.38	30 475.6 55.40
Volume (5)	34 165.4 52.10	32 243.2 55.38	32 243.3 55.38	33 536.2 52.10	33 536.3 52.10	32 684.9 52.10	32 684.9 52.10	33 442.3 53.04
Total Volume (6)	36 119.7 52.10	33 191.8 59.09	33 192.0 59.09	34 387.9 59.09	34 388.0 55.46	34 589.5 55.46	34 589.6 55.46	34 351.1 56.54
Random (7)	38 94.4 49.26	35 165.6 55.46	35 165.8 55.46	36 356.9 55.54	36 357.0 59.18	37 477.1 55.46	37 477.1 55.46	36 299.1 55.12
Number Boxes (8)	39 86.4 52.17	37 132.5 55.46	37 133.0 55.46	37 414.6 52.17	37 414.7 55.46	37 615.6 55.38	37 615.7 55.46	37 344.6 54.51
Mean	35 116.8 52.59	34 200.3 55.51	34 200.5 55.16	34 415.3 55.15	34 415.4 55.53	34 592.6 55.53	34 591.7 55.58	34 361.8 55.01

CASE 2: Standard Pallets Used
Number of Pallets/Time to Stack Pallets (secs)/Total % Volume Efficiency

TABLE III

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
99.000	1.000	52.000	44.000	48.000
100.000	1.000	50.000	42.000	39.000
101.000	1.000	49.000	42.000	38.000
73.000	1.000	46.000	44.000	34.000
105.000	1.000	48.000	42.000	26.000
153.000	1.000	48.000	42.000	4.000
104.000	1.000	48.000	42.000	40.000
102.000	1.000	48.000	40.000	72.000
86.000	1.000	48.000	40.000	62.000
78.000	1.000	47.000	40.000	43.000
83.000	1.000	43.000	43.000	46.000
72.000	1.000	46.000	40.000	20.000
81.000	1.000	43.000	36.000	51.000
51.000	2.000	65.000	21.000	19.000
50.000	1.000	47.000	26.000	15.000
11.000	1.000	46.000	26.000	30.000
120.000	1.000	50.000	22.000	8.000
9.000	3.000	34.000	26.000	5.000
59.000	1.000	35.000	25.000	5.000
88.000	1.000	36.000	24.000	28.000
71.000	1.000	35.000	23.000	24.000
3.000	1.000	27.000	27.000	7.000
87.000	1.000	27.000	24.000	18.000
54.000	3.000	57.000	11.000	10.000
69.000	1.000	25.000	25.000	16.000
8.000	4.000	25.000	25.000	8.000
55.000	5.000	60.000	10.000	6.000
48.000	2.000	29.000	20.000	31.000
65.000	1.000	32.000	18.000	22.000
66.000	1.000	32.000	18.000	15.000
67.000	1.000	32.000	18.000	20.000
20.000	1.000	24.000	24.000	35.000
68.000	2.000	25.000	23.000	15.000
70.000	1.000	25.000	23.000	23.000
127.000	4.000	26.000	22.000	14.000
60.000	12.000	27.000	20.000	18.000
19.000	7.000	23.000	23.000	30.000
31.000	1.000	26.000	20.000	28.000
14.000	4.000	25.000	20.000	27.000
144.000	1.000	26.000	18.000	16.000
79.000	2.000	24.000	19.000	15.000
80.000	2.000	24.000	19.000	13.000
93.000	1.000	24.000	19.000	32.000
82.000	1.000	24.000	18.000	29.000
138.000	2.000	22.000	19.000	15.000
13.000	2.000	26.000	16.000	18.000
18.000	1.000	26.000	16.000	15.000
84.000	2.000	26.000	15.000	17.000
130.000	3.000	24.000	16.000	20.000
85.000	1.000	24.000	16.000	10.000
139.000	3.000	20.000	19.000	10.000
116.000	1.000	21.000	16.000	19.000
23.000	8.000	18.000	18.000	8.000
126.000	1.000	23.000	14.000	15.000
46.000	2.000	20.000	16.000	21.000
137.000	1.000	20.000	16.000	17.000
2.000	2.000	20.000	15.000	8.000
47.000	1.000	20.000	15.000	31.000
10.000	1.000	21.000	14.000	12.000
35.000	5.000	21.000	14.000	7.000
151.000	69.000	18.000	16.000	14.000
77.000	3.000	20.000	14.000	12.000
142.000	2.000	20.000	13.000	16.000

SAMPLE DATA SORTED BY AREA

TABLE IV

143.000	3.000	16.000	16.000	5.000
150.000	27.000	16.000	16.000	16.000
112.000	6.000	18.000	14.000	6.000
115.000	2.000	20.000	12.000	14.000
17.000	1.000	16.000	15.000	12.000
53.000	4.000	18.000	13.000	14.000
152.000	80.000	19.000	12.000	7.000
121.000	2.000	16.000	14.000	9.000
124.000	3.000	16.000	14.000	22.000
106.000	2.000	20.000	11.000	10.000
135.000	3.000	18.000	12.000	9.000
148.000	9.000	18.000	12.000	6.000
29.000	4.000	18.000	12.000	8.000
98.000	158.000	18.000	12.000	7.000
154.000	12.000	15.000	14.000	14.000
114.000	25.000	23.000	9.000	10.000
141.000	1.000	17.000	12.000	14.000
49.000	14.000	22.000	9.000	10.000
118.000	3.000	14.000	14.000	8.000
36.000	7.000	16.000	12.000	8.000
33.000	2.000	18.000	10.000	8.000
28.000	2.000	16.000	11.000	18.000
44.000	18.000	16.000	11.000	6.000
22.000	50.000	13.000	13.000	12.000
30.000	4.000	16.000	10.000	8.000
45.000	1.000	13.000	12.000	13.000
16.000	4.000	13.000	12.000	10.000
113.000	1.000	14.000	11.000	10.000
24.000	12.000	19.000	8.000	9.000
140.000	2.000	15.000	10.000	12.000
34.000	4.000	15.000	10.000	8.000
89.000	1.000	12.000	12.000	16.000
41.000	3.000	12.000	12.000	7.000
52.000	1.000	12.000	12.000	13.000
21.000	1.000	12.000	12.000	15.000
1.000	4.000	14.000	10.000	8.000
95.000	12.000	12.000	11.000	9.000
107.000	16.000	22.000	6.000	9.000
32.000	2.000	13.000	10.000	7.000
103.000	3.000	13.000	10.000	12.000
136.000	1.000	11.000	11.000	10.000
96.000	7.000	12.000	10.000	8.000
147.000	4.000	12.000	10.000	10.000
57.000	2.000	15.000	8.000	8.000
15.000	11.000	12.000	10.000	10.000
97.000	3.000	20.000	6.000	8.000
39.000	24.000	12.000	10.000	8.000
133.000	10.000	13.000	9.000	4.000
149.000	2.000	14.000	8.000	10.000
40.000	2.000	11.000	10.000	7.000
111.000	12.000	12.000	9.000	5.000
110.000	8.000	12.000	9.000	14.000
12.000	1.000	12.000	9.000	9.000
75.000	14.000	12.000	9.000	6.000
6.000	6.000	12.000	9.000	7.000
38.000	12.000	12.000	9.000	8.000
128.000	2.000	13.000	8.000	10.000
94.000	4.000	13.000	8.000	8.000
131.000	60.000	10.000	10.000	8.000
5.000	14.000	12.000	8.000	6.000
58.000	8.000	12.000	8.000	9.000
125.000	20.000	12.000	8.000	7.000
117.000	17.000	12.000	8.000	5.000
108.000	8.000	12.000	8.000	18.000
63.000	10.000	12.000	8.000	8.000

SAMPLE DATA SORTED BY AREA

TABLE IV (CONTINUED)

109.000	8.000	12.000	8.000	13.000
56.000	3.000	13.000	7.000	6.000
134.000	3.000	10.000	9.000	11.000
90.000	2.000	11.000	8.000	10.000
43.000	5.000	11.000	8.000	8.000
76.000	24.000	14.000	6.000	16.000
7.000	6.000	9.000	9.000	6.000
129.000	5.000	10.000	8.000	8.000
74.000	3.000	10.000	8.000	6.000
4.000	20.000	10.000	8.000	9.000
145.000	6.000	9.000	8.000	7.000
27.000	42.000	9.000	8.000	9.000
37.000	5.000	12.000	6.000	8.000
25.000	6.000	9.000	8.000	6.000
146.000	14.000	10.000	7.000	7.000
132.000	2.000	8.000	8.000	8.000
61.000	18.000	8.000	8.000	6.000
42.000	4.000	9.000	7.000	6.000
155.000	27.000	9.000	7.000	7.000
62.000	26.000	10.000	6.000	6.000
92.000	10.000	8.000	7.000	6.000
91.000	4.000	8.000	7.000	8.000
123.000	20.000	9.000	6.000	5.000
64.000	12.000	9.000	6.000	8.000
122.000	16.000	8.000	6.000	5.000
119.000	60.000	8.000	6.000	8.000
26.000	8.000	7.000	6.000	4.000

SAMPLE DATA SORTED BY AREA

TABLE IV (CONTINUED)

```
PALLET NUMBER LENGTH     WIDTH     HEIGHT VOLUME      TIME   % EFFICIENCY
    1.0        52.0      44.0      96.0  209464.0      0.1      95.4
FOLLOWING BOXES WERE STACKED
 ID  NO   LENGTH    WIDTH   HEIGTH      X        Y        Z    X+BOXL   Y+BOXW   Z+BOXH
  99.0     52.0     44.0     48.0      0.0      0.0      0.0     52.0     44.0     48.0
 100.0     50.0     42.0     39.0      0.0      0.0     48.0     50.0     42.0     87.0
 153.0     48.0     42.0      4.0      0.0      0.0     87.0     48.0     42.0     91.0
   9.0     34.0     26.0      5.0      0.0      0.0     91.0     34.0     26.0     96.0
 143.0     16.0     16.0      5.0      0.0     26.0     91.0     16.0     42.0     96.0
 143.0     16.0     16.0      5.0     16.0     26.0     91.0     32.0     42.0     96.0
 143.0     16.0     16.0      5.0     32.0     26.0     91.0     48.0     42.0     96.0
 133.0     13.0      9.0      4.0     34.0      0.0     91.0     47.0      9.0     95.0
 133.0     13.0      9.0      4.0     34.0      9.0     91.0     47.0     18.0     95.0
 117.0     12.0      8.0      5.0     34.0     18.0     91.0     46.0     26.0     96.0
```

PALLET ONE CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE V

```
SUMMARY LINE FOR EACH PALET THAT WAS STACKED

PALLET NUMBER LENGTH      WIDTH      HEIGHT VOLUME        TIME   % EFFICIENCY

      1.00       52.00      44.00      96.00 209464.00     0.13      95.36
      2.00       49.00      42.00      96.00 185392.00     0.30      93.84
      3.00       46.00      44.00      95.00 177963.00     0.56      91.59
      4.00       48.00      42.00      96.00 183865.00     0.32      95.00
      5.00       48.00      40.00      96.00 178934.00     0.27      97.08
      6.00       48.00      40.00      96.00 170730.00     0.67      92.63
      7.00       43.00      36.00      96.00 140113.00     0.77      94.28
      8.00       65.00      21.00      96.00 122932.00     0.67      93.81
      9.00       50.00      22.00      96.00  84564.00     0.65      80.08
     10.00       35.00      23.00      95.00  57000.00     0.34      73.76
     11.00       27.00      24.00      96.00  51906.00     0.15      83.44
     12.00       25.00      25.00      95.00  52530.00     0.13      87.55
     13.00       26.00      22.00      93.00  50552.00     0.08      92.06
     14.00       27.00      20.00      96.00  51684.00     0.08      99.70
     15.00       27.00      20.00      96.00  51684.00     0.08      99.70
     16.00       27.00      20.00      95.00  46728.00     0.10      90.14
     17.00       23.00      23.00      96.00  50340.00     0.07      99.13
     18.00       23.00      23.00      96.00  50340.00     0.07      99.13
     19.00       25.00      20.00      92.00  41700.00     0.06      86.87
     20.00       26.00      16.00      96.00  36888.00     0.07      92.37
     21.00       24.00      16.00      94.00  32496.00     0.06      88.15
     22.00       18.00      18.00      95.00  27360.00     0.07      87.96
     23.00       20.00      16.00      92.00  27216.00     0.06      88.59
     24.00       18.00      16.00      96.00  27072.00     0.06      97.92
     25.00       18.00      16.00      93.00  26208.00     0.06      94.79
     26.00       18.00      16.00      93.00  26136.00     0.06      94.53
     27.00       18.00      16.00      93.00  26136.00     0.06      94.53
     28.00       18.00      16.00      93.00  26136.00     0.06      94.53
     29.00       18.00      16.00      96.00  26784.00     0.07      96.88
     30.00       18.00      16.00      96.00  26784.00     0.07      96.88
     31.00       18.00      16.00      96.00  26544.00     0.07      96.01
     32.00       18.00      16.00      92.00  25920.00     0.06      93.75
     33.00       18.00      16.00      92.00  25920.00     0.06      93.75
     34.00       18.00      16.00      96.00  25440.00     0.06      92.01
     35.00       20.00      13.00      95.00  22232.00     0.06      89.07
     36.00       16.00      16.00      96.00  24576.00     0.06     100.00
     37.00       16.00      16.00      96.00  24576.00     0.05     100.00
```

SUMMARY OF ALL PALLETS LOADED (LOADING WITHOUT STANDARD PALLETS)

TABLE VI

```
PALLET NUMBER LENGTH       WIDTH       HEIGHT VOLUME         TIME    % EFFICIENCY

    38.00        16.00        16.00       96.00  24576.00        0.06       100.00
    39.00        16.00        16.00       96.00  24576.00        0.05       100.00
    40.00        19.00        12.00       96.00  21558.00        0.09        98.49
    41.00        19.00        12.00       96.00  21558.00        0.09        98.49
    42.00        19.00        12.00       96.00  21558.00        0.09        98.49
    43.00        19.00        12.00       96.00  21558.00        0.09        98.49
    44.00        19.00        12.00       96.00  21558.00        0.09        98.49
    45.00        19.00        12.00       96.00  20886.00        0.08        95.42
    46.00        16.00        14.00       94.00  20664.00        0.04        96.09
    47.00        20.00        11.00       95.00  15300.00        0.07        72.44
    48.00        18.00        12.00       96.00  20466.00        0.08        98.70
    49.00        18.00        12.00       96.00  20406.00        0.08        98.41
    50.00        18.00        12.00       96.00  20406.00        0.08        98.41
    51.00        18.00        12.00       96.00  20406.00        0.08        98.41
    52.00        18.00        12.00       96.00  20406.00        0.08        98.41
    53.00        18.00        12.00       96.00  20406.00        0.08        98.41
    54.00        18.00        12.00       96.00  20406.00        0.08        98.41
    55.00        18.00        12.00       96.00  20376.00        0.08        98.26
    56.00        18.00        12.00       96.00  20376.00        0.08        98.26
    57.00        18.00        12.00       96.00  20376.00        0.08        98.26
    58.00        18.00        12.00       96.00  20376.00        0.08        98.26
    59.00        18.00        12.00       96.00  19344.00        0.07        93.29
    60.00        15.00        14.00       92.00  19208.00        0.05        95.28
    61.00        15.00        14.00       96.00  18952.00        0.06        94.01
    62.00        23.00         9.00       96.00  19764.00        0.05        99.46
    63.00        23.00         9.00       96.00  19764.00        0.05        99.46
    64.00        23.00         9.00       96.00  19494.00        0.05        98.10
    65.00        22.00         9.00       96.00  18954.00        0.05        99.72
    66.00        22.00         9.00       92.00  14904.00        0.05        78.41
    67.00        16.00        12.00       92.00  16320.00        0.06        88.54
    68.00        16.00        11.00       92.00  13624.00        0.06        80.63
    69.00        13.00        13.00       96.00  16224.00        0.05       100.00
    70.00        13.00        13.00       96.00  16224.00        0.05       100.00
    71.00        13.00        13.00       96.00  16224.00        0.05       100.00
    72.00        13.00        13.00       96.00  16224.00        0.05       100.00
    73.00        13.00        13.00       96.00  16224.00        0.05       100.00
    74.00        13.00        13.00       96.00  16224.00        0.05       100.00
    75.00        13.00        12.00       96.00  14244.00        0.05        95.11
    76.00        19.00         8.00       96.00  10568.00        0.07        72.42
```

SUMMARY OF ALL PALLETS LOADED (LOADING WITHOUT STANDARD PALLETS)

TABLE VI (CONTINUED)

PALLET NUMBER	LENGTH	WIDTH	HEIGHT	VOLUME	TIME	% EFFICIENCY
77.00	15.00	10.00	96.00	12240.00	0.04	85.00
78.00	12.00	12.00	96.00	12828.00	0.05	92.80
79.00	12.00	11.00	93.00	11090.00	0.04	87.52
80.00	22.00	6.00	96.00	12600.00	0.03	99.43
81.00	22.00	6.00	95.00	9036.00	0.04	71.31
82.00	12.00	10.00	96.00	11448.00	0.04	99.37
83.00	12.00	10.00	92.00	11040.00	0.04	95.83
84.00	12.00	10.00	96.00	11520.00	0.04	100.00
85.00	12.00	10.00	92.00	10704.00	0.04	92.92
86.00	12.00	9.00	93.00	10044.00	0.03	96.88
87.00	12.00	9.00	96.00	10296.00	0.04	99.31
88.00	12.00	9.00	96.00	10368.00	0.04	100.00
89.00	10.00	10.00	96.00	9600.00	0.04	100.00
90.00	10.00	10.00	96.00	9600.00	0.04	100.00
91.00	10.00	10.00	96.00	9600.00	0.04	100.00
92.00	10.00	10.00	96.00	9600.00	0.04	100.00
93.00	10.00	10.00	94.00	9180.00	0.03	95.62
94.00	12.00	8.00	93.00	8928.00	0.04	96.88
95.00	12.00	8.00	94.00	9024.00	0.03	97.92
96.00	12.00	8.00	96.00	9216.00	0.04	100.00
97.00	12.00	8.00	95.00	9120.00	0.02	98.96
98.00	12.00	8.00	96.00	9216.00	0.02	100.00
99.00	12.00	8.00	95.00	9056.00	0.02	98.26
100.00	12.00	8.00	95.00	8640.00	0.02	93.75
101.00	10.00	9.00	92.00	6930.00	0.03	80.21
102.00	14.00	6.00	96.00	8064.00	0.01	100.00
103.00	14.00	6.00	96.00	8064.00	0.01	100.00
104.00	14.00	6.00	96.00	8064.00	0.01	100.00
105.00	10.00	8.00	94.00	7520.00	0.02	97.92
106.00	10.00	8.00	96.00	7632.00	0.02	99.37
107.00	10.00	8.00	96.00	7056.00	0.02	91.87
108.00	9.00	8.00	96.00	6912.00	0.02	100.00
109.00	9.00	8.00	96.00	6912.00	0.02	100.00
110.00	9.00	8.00	96.00	6864.00	0.02	99.31
111.00	9.00	8.00	96.00	6136.00	0.03	88.77
112.00	12.00	6.00	96.00	6048.00	0.03	87.50
113.00	10.00	7.00	96.00	6610.00	0.02	98.36
114.00	10.00	7.00	96.00	6097.00	0.02	90.73
115.00	8.00	8.00	96.00	5664.00	0.03	92.19

SUMMARY OF ALL PALLETS LOADED (LOADING WITHOUT STANDARD PALLETS)

TABLE VI (CONTINUED)

```
PALLET NUMBER LENGTH      WIDTH      HEIGHT VOLUME        TIME    % EFFICIENCY

   116.00        9.00      7.00      96.00   5973.00       0.02       98.76
   117.00        9.00      7.00      90.00   4891.00       0.02       80.87
   118.00       10.00      6.00      96.00   5472.0C       C.C3       95.00
   119.C0        9.00      6.00      96.00   4896.00       0.02       94.44
   120.00        8.00      6.00      96.CC   4608.0C       0.02      100.00
   121.00        8.00      6.00      96.00   4608.0C       0.02      100.00
   122.00        8.00      6.00      96.00   4608.00       0.02      100.00
   123.00        8.00      6.00      96.CC   4608.00       0.02      100.00
   124.00        8.00      6.00      16.00    768.00       0.00       16.67
```

SUMMARY OF ALL PALLETS LOADED (LOADING WITHOUT STANDARD PALLETS)

TABLE VI (CONTINUED)

```
CONTAINER NR   LENGTH      WIDTH      HEIGHT VOLUME       TIME    % EFFICIENCY
     1.0        96.0      480.0       96.0 3819456.0       3.0        86.3
FOLLOWING BOXES WERE STACKED
  ID   NR  LENGTH     WIDTH   HEIGTH       X        Y         Z    X+BOXL  Y+BOXW   Z+BOXH
     1.0    44.0     52.0     96.0     21.0      0.0      0.0     65.0     52.0     96.0
     9.0    22.0     50.0     96.0     65.0      0.0      0.0     87.0     50.0     96.0
     2.0    42.0     49.0     96.0      0.0     65.0      0.0     42.0    114.0     96.0
     4.0    42.0     48.0     96.0     42.0     52.0      0.0     84.0    100.0     96.0
     5.0    40.0     48.0     96.0      0.0    114.0      0.0     40.0    162.0     96.0
     6.0    40.0     48.0     96.0     40.0    114.0      0.0     80.0    162.0     96.0
     3.0    44.0     46.0     96.0      0.0    162.0      0.0     44.0    208.0     96.0
     7.0    36.0     43.0     96.0     44.0    162.0      0.0     80.0    205.0     96.0
    10.0    23.0     35.0     96.0      0.0    208.0      0.0     23.0    243.0     96.0
    11.0    24.0     27.0     96.0     23.0    208.0      0.0     47.0    235.0     96.0
    14.0    20.0     27.0     96.0     47.0    205.0      0.0     67.0    232.0     96.0
    15.0    20.0     27.0     96.0     67.0    205.0      0.0     87.0    232.0     96.0
    16.0    20.0     27.0     96.0      0.0    243.0      0.0     20.0    270.0     96.0
    20.0    16.0     26.0     96.0     80.0    100.0      0.0     96.0    126.0     96.0
    13.0    22.0     26.0     96.0     20.0    243.0      0.0     42.0    269.0     96.0
    19.0    20.0     25.0     96.0     42.0    235.0      0.0     62.0    260.0     96.0
    12.0    25.0     25.0     96.0     62.0    232.0      0.0     87.0    257.0     96.0
```

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII

ID NR	LENGTH	WIDTH	HEIGTH	X	Y	Z	X+BOXL	Y+BOXW	Z+BOXH
21.0	16.0	24.0	96.0	80.0	126.0	0.0	96.0	150.0	96.0
18.0	23.0	23.0	96.0	0.0	270.0	0.0	23.0	293.0	96.0
17.0	23.0	23.0	96.0	23.0	269.0	0.0	46.0	292.0	96.0
63.0	9.0	23.0	96.0	87.0	0.0	0.0	96.0	23.0	96.0
64.0	9.0	23.0	96.0	84.0	50.0	0.0	93.0	73.0	96.0
62.0	9.0	23.0	96.0	80.0	150.0	0.0	89.0	173.0	96.0
81.0	6.0	22.0	96.0	80.0	173.0	0.0	86.0	195.0	96.0
65.0	9.0	22.0	96.0	46.0	260.0	0.0	55.0	282.0	96.0
66.0	9.0	22.0	96.0	86.0	173.0	0.0	95.0	195.0	96.0
80.0	6.0	22.0	96.0	89.0	150.0	0.0	95.0	172.0	96.0
35.0	13.0	20.0	96.0	55.0	260.0	0.0	68.0	280.0	96.0
23.0	16.0	20.0	96.0	68.0	257.0	0.0	84.0	277.0	96.0
47.0	11.0	20.0	96.0	84.0	257.0	0.0	95.0	277.0	96.0
45.0	12.0	19.0	96.0	0.0	293.0	0.0	12.0	312.0	96.0
44.0	12.0	19.0	96.0	12.0	293.0	0.0	24.0	312.0	96.0
43.0	12.0	19.0	96.0	24.0	292.0	0.0	36.0	311.0	96.0
76.0	8.0	19.0	96.0	36.0	292.0	0.0	44.0	311.0	96.0
40.0	12.0	19.0	96.0	44.0	292.0	0.0	56.0	311.0	96.0
41.0	12.0	19.0	96.0	56.0	280.0	0.0	68.0	299.0	96.0
42.0	12.0	19.0	96.0	68.0	277.0	0.0	80.0	296.0	96.0

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII (CONTINUED)

ID NR	LENGTH	WIDTH	HEIGTH	X	Y	Z	X+BOXL	Y+BCXW	Z+BCXH
8.0	21.0	65.0	96.0	0.0	0.0	0.0	21.0	65.0	96.0
34.0	16.0	18.0	96.0	80.0	277.0	0.0	96.0	295.0	96.0
33.0	16.0	18.0	96.0	0.0	312.0	0.0	16.0	330.0	96.0
22.0	18.0	18.0	96.0	16.0	312.0	0.0	34.0	330.0	96.0
31.0	16.0	18.0	96.0	34.0	311.0	0.0	50.0	329.0	96.0
48.0	12.0	18.0	96.0	50.0	311.0	0.0	62.0	329.0	96.0
30.0	16.0	18.0	96.0	62.0	299.0	0.0	78.0	317.0	96.0
29.0	16.0	18.0	96.0	78.0	296.0	0.0	94.0	314.0	96.0
28.0	16.0	18.0	96.0	0.0	330.0	0.0	16.0	348.0	96.0
50.0	12.0	18.0	96.0	16.0	330.0	0.0	28.0	348.0	96.0
51.0	12.0	18.0	96.0	28.0	330.0	0.0	40.0	348.0	96.0
49.0	12.0	18.0	96.0	40.0	329.0	0.0	52.0	347.0	96.0
52.0	12.0	18.0	96.0	52.0	329.0	0.0	64.0	347.0	96.0
53.0	12.0	18.0	96.0	64.0	317.0	0.0	76.0	335.0	96.0
54.0	12.0	18.0	96.0	76.0	317.0	0.0	88.0	335.0	96.0
55.0	12.0	18.0	96.0	84.0	73.0	0.0	96.0	91.0	96.0
56.0	12.0	18.0	96.0	0.0	348.0	0.0	12.0	366.0	96.0
57.0	12.0	18.0	96.0	12.0	348.0	0.0	24.0	366.0	96.0
58.0	12.0	18.0	96.0	24.0	348.0	0.0	36.0	366.0	96.0
59.0	12.0	18.0	96.0	36.0	348.0	0.0	48.0	366.0	96.0

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII (CONTINUED)

IC NR	LENGTH	WIDTH	HEIGTH	X	Y	Z	X+BOXL	Y+BOXW	Z+BOXH
27.0	16.0	18.0	96.0	48.0	347.0	0.0	64.0	365.0	96.0
26.0	16.0	18.0	96.0	64.0	335.0	0.0	80.0	353.0	96.0
25.0	16.0	18.0	96.0	80.0	335.0	0.0	96.0	353.0	96.0
24.0	16.0	18.0	96.0	0.0	366.0	0.0	16.0	384.0	96.0
32.0	16.0	18.0	96.0	16.0	366.0	0.0	32.0	384.0	96.0
67.0	12.0	16.0	96.0	32.0	366.0	0.0	44.0	382.0	96.0
36.0	16.0	16.0	96.0	44.0	366.0	0.0	60.0	382.0	96.0
37.0	16.0	16.0	96.0	60.0	365.0	0.0	76.0	381.0	96.0
68.0	11.0	16.0	96.0	76.0	353.0	0.0	87.0	369.0	96.0
39.0	16.0	16.0	96.0	0.0	384.0	0.0	16.0	400.0	96.0
46.0	14.0	16.0	96.0	16.0	384.0	0.0	30.0	400.0	96.0
38.0	16.0	16.0	96.0	30.0	384.0	0.0	46.0	400.0	96.0
60.0	14.0	15.0	96.0	46.0	382.0	0.0	60.0	397.0	96.0
77.0	10.0	15.0	96.0	60.0	381.0	0.0	70.0	396.0	96.0
61.0	14.0	15.0	96.0	70.0	381.0	0.0	84.0	396.0	96.0
102.0	6.0	14.0	96.0	88.0	314.0	0.0	94.0	328.0	96.0
104.0	6.0	14.0	96.0	87.0	353.0	0.0	93.0	367.0	96.0
103.0	6.0	14.0	96.0	84.0	369.0	0.0	90.0	383.0	96.0
72.0	13.0	13.0	96.0	21.0	52.0	0.0	34.0	65.0	96.0
75.0	12.0	13.0	96.0	42.0	100.0	0.0	54.0	113.0	96.0

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII (CONTINUED)

ID NR	LENGTH	WIDTH	HEIGTH	X	Y	Z	X+BOXL	Y+BOXW	Z+BOXH
71.0	13.0	13.0	96.0	54.0	100.0	0.0	67.0	113.0	96.0
70.0	13.0	13.0	96.0	67.0	100.0	0.0	80.0	113.0	96.0
74.0	13.0	13.0	96.0	0.0	400.0	0.0	13.0	413.0	96.0
73.0	13.0	13.0	96.0	13.0	400.0	0.0	26.0	413.0	96.0
69.0	13.0	13.0	96.0	26.0	400.0	0.0	39.0	413.0	96.0
87.0	9.0	12.0	96.0	39.0	400.0	0.0	48.0	412.0	96.0
88.0	9.0	12.0	96.0	48.0	397.0	0.0	57.0	409.0	96.0
95.0	8.0	12.0	96.0	34.0	52.0	0.0	42.0	64.0	96.0
86.0	9.0	12.0	96.0	57.0	397.0	0.0	66.0	409.0	96.0
85.0	10.0	12.0	96.0	66.0	396.0	0.0	76.0	408.0	96.0
84.0	10.0	12.0	96.0	76.0	396.0	0.0	86.0	408.0	96.0
78.0	12.0	12.0	96.0	64.0	353.0	0.0	76.0	365.0	96.0
94.0	8.0	12.0	96.0	84.0	383.0	0.0	92.0	395.0	96.0
82.0	10.0	12.0	96.0	0.0	413.0	0.0	10.0	425.0	96.0
83.0	10.0	12.0	96.0	10.0	413.0	0.0	20.0	425.0	96.0
112.0	6.0	12.0	96.0	90.0	367.0	0.0	96.0	379.0	96.0
99.0	8.0	12.0	96.0	20.0	413.0	0.0	28.0	425.0	96.0
98.0	8.0	12.0	96.0	28.0	413.0	0.0	36.0	425.0	96.0
96.0	8.0	12.0	96.0	36.0	413.0	0.0	44.0	425.0	96.0
97.0	8.0	12.0	96.0	44.0	412.0	0.0	52.0	424.0	96.0
100.0	8.0	12.0	96.0	52.0	409.0	0.0	60.0	421.0	96.0

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII (CONTINUED)

ID NR	LENGTH	WIDTH	HEIGTH	X	Y	Z	X+BOXL	Y+BOXW	Z+BOXH
79.0	11.0	12.0	96.0	60.0	409.0	0.0	71.0	421.0	96.0
89.0	10.0	10.0	96.0	71.0	408.0	0.0	81.0	418.0	96.0
90.0	10.0	10.0	96.0	81.0	408.0	0.0	91.0	418.0	96.0
101.0	9.0	10.0	96.0	87.0	23.0	0.0	96.0	33.0	96.0
92.0	10.0	10.0	96.0	80.0	195.0	0.0	90.0	205.0	96.0
91.0	10.0	10.0	96.0	46.0	282.0	0.0	56.0	292.0	96.0
105.0	8.0	10.0	96.0	76.0	369.0	0.0	84.0	379.0	96.0
106.0	8.0	10.0	96.0	0.0	425.0	0.0	8.0	435.0	96.0
107.0	8.0	10.0	96.0	8.0	425.0	0.0	16.0	435.0	96.0
118.0	6.0	10.0	96.0	90.0	195.0	0.0	96.0	205.0	96.0
93.0	10.0	10.0	96.0	16.0	425.0	0.0	26.0	435.0	96.0
113.0	7.0	10.0	96.0	26.0	425.0	0.0	33.0	435.0	96.0
114.0	7.0	10.0	96.0	33.0	425.0	0.0	40.0	435.0	96.0
108.0	8.0	9.0	96.0	40.0	425.0	0.0	48.0	434.0	96.0
110.0	8.0	9.0	96.0	48.0	424.0	0.0	56.0	433.0	96.0
111.0	8.0	9.0	96.0	56.0	421.0	0.0	64.0	430.0	96.0
116.0	7.0	9.0	96.0	64.0	421.0	0.0	71.0	430.0	96.0
117.0	7.0	9.0	96.0	71.0	418.0	0.0	78.0	427.0	96.0
109.0	8.0	9.0	96.0	78.0	418.0	0.0	86.0	427.0	96.0
119.0	6.0	9.0	96.0	86.0	418.0	0.0	92.0	427.0	96.0

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII (CONTINUED)

ID NR	LENGTH	WIDTH	HEIGTH	X	Y	Z	X+BOXL	Y+BOXW	Z+BOXH
115.0	8.0	8.0	96.0	23.0	235.0	0.0	31.0	243.0	96.0
120.0	6.0	8.0	96.0	31.0	235.0	0.0	37.0	243.0	96.0
121.0	6.0	8.0	96.0	56.0	299.0	0.0	62.0	307.0	96.0
122.0	6.0	8.0	96.0	84.0	91.0	0.0	90.0	59.0	96.0
123.0	6.0	8.0	96.0	90.0	91.0	0.0	56.0	99.0	96.0
124.0	6.0	8.0	96.0	87.0	33.0	0.0	93.0	41.0	96.0

CONTAINER CONFIGURATION (LOADING WITHOUT STANDARD PALLETS)

TABLE VII (CONTINUED)

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
102.000	1.000	48.000	40.000	72.000
86.000	1.000	48.000	40.000	62.000
81.000	1.000	43.000	36.000	51.000
99.000	1.000	52.000	44.000	48.000
83.000	1.000	43.000	43.000	46.000
78.000	1.000	47.000	40.000	43.000
104.000	1.000	48.000	42.000	40.000
100.000	1.000	50.000	42.000	39.000
101.000	1.000	49.000	42.000	38.000
20.000	1.000	24.000	24.000	35.000
73.000	1.000	46.000	44.000	34.000
93.000	1.000	24.000	19.000	32.000
47.000	1.000	20.000	15.000	31.000
48.000	2.000	29.000	20.000	31.000
11.000	1.000	46.000	26.000	30.000
19.000	7.000	23.000	23.000	30.000
82.000	1.000	24.000	18.000	29.000
31.000	1.000	26.000	20.000	28.000
88.000	1.000	36.000	24.000	28.000
14.000	4.000	25.000	20.000	27.000
105.000	1.000	48.000	42.000	26.000
71.000	1.000	35.000	23.000	24.000
70.000	1.000	25.000	23.000	23.000
65.000	1.000	32.000	18.000	22.000
124.000	3.000	16.000	14.000	22.000
46.000	2.000	20.000	16.000	21.000
67.000	1.000	32.000	18.000	20.000
130.000	3.000	24.000	16.000	20.000
72.000	1.000	46.000	40.000	20.000
51.000	2.000	65.000	21.000	19.000
116.000	1.000	21.000	16.000	19.000
60.000	12.000	27.000	20.000	18.000
28.000	2.000	16.000	11.000	18.000
108.000	8.000	12.000	8.000	18.000
13.000	2.000	26.000	16.000	18.000
87.000	1.000	27.000	24.000	18.000
84.000	2.000	26.000	15.000	17.000
137.000	1.000	20.000	16.000	17.000
150.000	27.000	16.000	16.000	16.000
89.000	1.000	12.000	12.000	16.000
69.000	1.000	25.000	25.000	16.000
142.000	2.000	20.000	13.000	16.000
76.000	24.000	14.000	6.000	16.000
144.000	1.000	26.000	18.000	16.000
126.000	1.000	23.000	14.000	15.000
18.000	1.000	26.000	16.000	15.000
68.000	2.000	25.000	23.000	15.000
66.000	1.000	32.000	18.000	15.000
21.000	1.000	12.000	12.000	15.000
50.000	1.000	47.000	26.000	15.000
79.000	2.000	24.000	19.000	15.000
138.000	2.000	22.000	19.000	15.000
115.000	2.000	20.000	12.000	14.000
110.000	8.000	12.000	9.000	14.000
53.000	4.000	18.000	13.000	14.000
154.000	12.000	15.000	14.000	14.000
151.000	69.000	18.000	16.000	14.000
127.000	4.000	26.000	22.000	14.000
141.000	1.000	17.000	12.000	14.000
80.000	2.000	24.000	19.000	13.000
45.000	1.000	13.000	12.000	13.000
109.000	8.000	12.000	8.000	13.000

SAMPLE DATA SORTED BY HEIGHT

TABLE VIII

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
52.000	1.000	12.000	12.000	13.000
77.000	3.000	20.000	14.000	12.000
22.000	50.000	13.000	13.000	12.000
140.000	2.000	15.000	10.000	12.000
103.000	3.000	13.000	10.000	12.000
17.000	1.000	16.000	15.000	12.000
10.000	1.000	21.000	14.000	12.000
134.000	3.000	10.000	9.000	11.000
15.000	11.000	12.000	10.000	10.000
114.000	25.000	23.000	9.000	10.000
90.000	2.000	11.000	8.000	10.000
54.000	3.000	57.000	11.000	10.000
147.000	4.000	12.000	10.000	10.000
149.000	2.000	14.000	8.000	10.000
85.000	1.000	24.000	16.000	10.000
128.000	2.000	13.000	8.000	10.000
113.000	1.000	14.000	11.000	10.000
106.000	2.000	20.000	11.000	10.000
49.000	14.000	22.000	9.000	10.000
136.000	1.000	11.000	11.000	10.000
16.000	4.000	13.000	12.000	10.000
139.000	3.000	20.000	19.000	10.000
58.000	8.000	12.000	8.000	9.000
107.000	16.000	22.000	6.000	9.000
135.000	3.000	18.000	12.000	9.000
24.000	12.000	19.000	8.000	9.000
4.000	20.000	10.000	8.000	9.000
95.000	12.000	12.000	11.000	9.000
27.000	42.000	9.000	8.000	9.000
12.000	1.000	12.000	9.000	9.000
121.000	2.000	16.000	14.000	9.000
131.000	60.000	10.000	10.000	8.000
38.000	12.000	12.000	9.000	8.000
96.000	7.000	12.000	10.000	8.000
43.000	5.000	11.000	8.000	8.000
57.000	2.000	15.000	8.000	8.000
63.000	10.000	12.000	8.000	8.000
64.000	12.000	9.000	6.000	8.000
29.000	4.000	18.000	12.000	8.000
30.000	4.000	16.000	10.000	8.000
91.000	4.000	8.000	7.000	8.000
33.000	2.000	18.000	10.000	8.000
120.000	1.000	50.000	22.000	8.000
34.000	4.000	15.000	10.000	8.000
129.000	5.000	10.000	8.000	8.000
97.000	3.000	20.000	6.000	8.000
23.000	8.000	18.000	18.000	8.000
94.000	4.000	13.000	8.000	8.000
36.000	7.000	16.000	12.000	8.000
37.000	6.000	12.000	6.000	8.000
1.000	4.000	14.000	10.000	8.000
8.000	4.000	25.000	25.000	8.000
39.000	24.000	12.000	10.000	8.000
2.000	2.000	20.000	15.000	8.000
118.000	3.000	14.000	14.000	8.000
119.000	60.000	8.000	6.000	8.000
132.000	2.000	8.000	8.000	8.000
152.000	80.000	19.000	12.000	7.000
146.000	14.000	10.000	7.000	7.000
125.000	20.000	12.000	8.000	7.000
32.000	2.000	13.000	10.000	7.000
155.000	27.000	9.000	7.000	7.000

SAMPLE DATA SORTED BY HEIGHT

TABLE VIII (CONTINUED)

NR LINE	NR BOXES	LENGTH	WIDTH	HEIGHT
3.000	1.000	27.000	27.000	7.000
145.000	6.000	9.000	8.000	7.000
35.000	5.000	21.000	14.000	7.000
6.000	6.000	12.000	9.000	7.000
98.000	158.000	18.000	12.000	7.000
40.000	2.000	11.000	10.000	7.000
41.000	3.000	12.000	12.000	7.000
92.000	10.000	8.000	7.000	6.000
75.000	14.000	12.000	9.000	6.000
62.000	26.000	10.000	6.000	6.000
61.000	18.000	8.000	8.000	6.000
55.000	5.000	60.000	10.000	6.000
56.000	3.000	13.000	7.000	6.000
44.000	18.000	16.000	11.000	6.000
42.000	4.000	9.000	7.000	6.000
7.000	6.000	9.000	9.000	6.000
74.000	3.000	10.000	8.000	6.000
148.000	9.000	18.000	12.000	6.000
112.000	6.000	18.000	14.000	6.000
5.000	14.000	12.000	8.000	6.000
25.000	6.000	9.000	8.000	6.000
59.000	1.000	35.000	25.000	5.000
117.000	17.000	12.000	8.000	5.000
123.000	20.000	9.000	6.000	5.000
9.000	3.000	34.000	26.000	5.000
111.000	12.000	12.000	9.000	5.000
122.000	16.000	8.000	6.000	5.000
143.000	3.000	16.000	16.000	5.000
153.000	1.000	48.000	42.000	4.000
133.000	10.000	13.000	9.000	4.000
26.000	8.000	7.000	6.000	4.000

SAMPLE DATA SORTED BY HEIGHT

TABLE VIII (CONTINUED)

```
PALLET NUMBER LENGTH      WIDTH       HEIGHT VOLUME        TIME   % EFFICIENCY
   1.0        48.0        40.0        96.C  184272.0        0.5     100.0
FOLLCWING BOXES WERE STACKEC
 ID  NR  LENGTH    WIDTH  HEIGTH        X        Y        Z   X+BOXL  Y+BOXW   Z+BOXH
 102.0    48.0     40.0    72.0       0.0      0.0      0.0    48.C    40.0     72.0

  20.0    24.0     35.0    24.0       0.C      0.0     72.0    24.0    35.0     96.0

  93.0    24.0     32.0    19.0      24.0      0.0     72.0    48.0    32.0     91.0

 108.0    12.0      8.0    18.0      24.0     32.0     72.0    36.0    40.0     90.0
 108.0    12.0      8.0    18.0      36.0     32.0     72.0    48.0    40.0     90.0

  64.0     9.0      8.0     6.0      24.0     32.0     90.0    33.0    40.0     96.0
  64.C     9.0      8.0     6.0      33.0     32.0     90.0    42.0    40.0     96.0

 117.0    12.0      8.0     5.0      24.0      0.0     91.0    36.0     8.0     96.0

 117.0    12.0      8.0     5.0      36.0      0.0     91.0    48.C     8.0     96.0

 117.0    12.0      8.0     5.0      24.C      8.0     91.0    36.0    16.0     96.0

 117.C    12.0      8.0     5.0      36.0      8.0     91.0    48.0    16.0     96.0

 117.0    12.0      8.0     5.0      24.0     16.0     91.0    36.C    24.0     96.0

 117.0    12.0      8.0     5.0      36.0     16.0     91.0    48.C    24.0     96.0

 117.0    12.0      8.0     5.0      24.C     24.0     91.0    36.0    32.0     96.0

 117.0    12.0      8.0     5.0      36.0     24.0     91.0    48.0    32.0     96.0

 117.0    12.0      5.0     8.0       0.0     35.0     72.0    12.0    40.0     8C.0

 117.0    12.0      5.0     8.0      12.0     35.0     72.0    24.0    40.0     80.0

 117.C    12.0      5.0     8.0       0.C     35.0     80.0    12.0    40.0     88.0

 117.C    12.0      5.0     8.0      12.0     35.0     80.0    24.0    40.0     88.0

 117.0    12.0      5.0     8.0       0.0     35.0     88.0    12.0    40.0     96.0

 117.0    12.0      5.0     8.0      12.0     35.0     88.0    24.C    40.0     96.0

 122.0     6.0      8.0     5.0      42.C     32.0     90.0    48.0    40.0     95.0
```

PALLET ONE CCNFIGURATION (LCACIING WITH STANDARD PALLETS)
TABLE IX

```
SUMMARY LINE FOR EACH FALET THAT WAS STACKED

PALLET NUMBER LENGTH      WIDTH      HEIGHT VOLUME        TIME   % EFFICIENCY

      1.00       48.00      40.00      96.00 184272.00      0.49      99.97
      2.00       48.00      40.00      96.CC 173462.0C      1.33      94.11
      3.00       43.00      36.00      96.00 137730.00      3.18      92.68
      4.00       52.00      44.00      96.CC 206974.00      0.81      94.23
      5.00       47.00      40.00      95.00 169816.0C      1.C7      94.09
      6.00       48.00      42.00      96.00 184524.00      1.26      95.34
      7.00       49.00      42.00      96.CC 172856.0C      5.32      87.49
      8.00       48.0)      42.00      96.00 179498.00      7.40      92.75
      9.00       46.00      40.00      96.00 131466.00     15.16      74.43
     10.00       65.00      21.00      96.00 117259.0C      1.58      89.48
     11.00       65.00      21.00      96.00 120927.00      2.37      92.28
     12.00       47.00      26.00      96.CC  91541.0C      6.64      78.03
     13.00       57.00      11.00      96.00  43950.0C      4.55      73.02
     14.00       57.00      11.00      96.00  46860.00      3.50      77.85
     15.00       50.00      22.00      96.CC  79032.00      6.74      74.84
     16.00       60.00      10.00      96.00  24648.00      2.68      42.79
     17.00       60.00      10.00      96.00  22500.00      3.83      39.06
     18.00       60.00      10.00      96.00  34160.CC      2.81      59.31
     19.00       60.00      10.00      96.00  40704.00     12.08      70.67
     20.00       60.00      10.00      96.CC  30186.0C      7.99      52.41
     21.00       48.00      42.00      96.00 144940.0C    147.87      74.89
     22.00       40.00      44.00      96.00  85494.00     12.83      50.60
     23.00       40.00      44.00      95.0C  91194.0C     34.02      53.97
     24.00       40.00      44.00      96.00 121072.00     46.57      71.66
     25.00       40.0C      44.00      96.00 151516.00      9.72      89.68
     26.00       40.00      44.00      96.00 131420.0C     14.63      77.78
     27.00       40.00      44.00      96.00 118176.00      9.28      69.94
     28.00       40.00      44.00      96.0C  76295.0C     10.60      45.16
     29.00       40.00      44.00      96.0C 150885.0C     14.71      89.30
     30.00       40.00      44.00      91.00  80221.00     15.81      47.48
     31.00       40.00      44.00      96.CC 146548.0C      9.62      86.74
     32.00       40.00      44.00      89.00  82400.00      2.20      48.77
```

SUMMARY OF ALL PALLETS LOADED (LOADING WITH STANDARD PALLETS)

TABLE X

```
CONTAINER NR  LENGTH      WIDTH      HEIGHT VOLUME       TIME    % EFFICIENCY
     1.0       96.0      480.0       96.0 3461760.0       0.5       78.3

FOLLOWING BOXES WERE STACKED
  ID  NR   LENGTH    WIDTH  HEIGTH        X        Y         Z    X+BOXL  Y+BOXW   Z+BOXH
   10.0     21.0     65.0    96.0       0.0      0.0       0.0    21.0     65.0     96.0
   11.0     21.0     65.0    96.0      21.0      0.0       0.0    42.0     65.0     96.0
   17.0     10.0     60.0    96.0      42.0      0.0       0.0    52.0     60.0     96.0
   18.0     10.0     60.0    96.0      52.0      0.0       0.0    62.0     60.0     96.0
   19.0     10.0     60.0    96.0      62.0      0.0       0.0    72.0     60.0     96.0
   20.0     10.0     60.0    96.0      72.0      0.0       0.0    82.0     60.0     96.0
   16.0     10.0     60.0    96.0      82.0      0.0       0.0    92.0     60.0     96.0
   14.0     11.0     57.0    96.0       0.0     65.0       0.0    11.0    122.0     96.0
   13.0     11.0     57.0    96.0      11.0     65.0       0.0    22.0    122.0     96.0
    4.0     44.0     52.0    96.0      22.0     65.0       0.0    66.0    117.0     96.0
   15.0     22.0     50.0    96.0      66.0     60.0       0.0    88.0    110.0     96.0
    7.0     42.0     49.0    96.0       0.0    122.0       0.0    42.0    171.0     96.0
    8.0     42.0     48.0    96.0      42.0    117.0       0.0    84.0    165.0     96.0
    6.0     42.0     48.0    96.0       0.0    171.0       0.0    42.0    219.0     96.0
    2.0     40.0     48.0    96.0      42.0    165.0       0.0    82.0    213.0     96.0
    1.0     40.0     48.0    96.0       0.0    219.0       0.0    40.0    267.0     96.0
```

CONTAINER CONFIGURATION (LOADING WITH STANDARD PALLETS)

TABLE XI

```
  ID   NR   LENGTH    WIDTH    HEIGTH       X         Y          Z     X+BOXL    Y+BOXW    Z+BOXH
   21.0      42.0      48.0      96.0     40.0     219.0       0.0      82.0     267.0      96.0
    5.0      40.0      47.0      96.0      0.0     267.0       0.0      40.0     314.0      96.0
   12.0      26.0      47.0      96.0     40.0     267.0       0.0      66.0     314.0      96.0
    9.0      40.0      46.0      96.0      0.0     314.0       0.0      40.0     360.0      96.0
   22.0      40.0      44.0      96.0     40.0     314.0       0.0      80.0     358.0      96.0
   23.0      40.0      44.0      96.0      0.0     360.0       0.0      40.0     404.0      96.0
   25.0      40.0      44.0      96.0     40.0     358.0       0.0      80.0     402.0      96.0
   26.0      40.0      44.0      96.0      0.0     404.0       0.0      40.0     448.0      96.0
   27.0      40.0      44.0      96.0     40.0     402.0       0.0      80.0     446.0      96.0

CONTAINER NR   LENGTH      WIDTH      HEIGHT VOLUME       TIME    % EFFICIENCY
      2.0        96.0      480.0      96.0 1162368.0       0.0        26.3
FOLLOWING BOXES WERE STACKED
  ID   NR   LENGTH    WIDTH    HEIGTH       X         Y          Z     X+BOXL    Y+BOXW    Z+BOXH
   28.0      40.0      44.0      96.0      0.0       0.0       0.0      40.0      44.0      96.0
   29.0      40.0      44.0      96.0     40.0       0.0       0.0      80.0      44.0      96.0
   24.0      40.0      44.0      96.0      0.0      44.0       0.0      40.0      88.0      96.0
   30.0      40.0      44.0      96.0     40.0      44.0       0.0      80.0      88.0      96.0
   32.0      40.0      44.0      96.0      0.0      88.0       0.0      40.0     132.0      96.0
   31.0      40.0      44.0      96.0     40.0      88.0       0.0      80.0     132.0      96.0
    3.0      36.0      43.0      96.0      0.0     132.0       0.0      36.0     175.0      96.0
```

CONTAINER CONFIGURATION (LOADING WITH STANDARD PALLETS)

TABLE XI (CONTINUED)

	No Sort (0)	Height (1)	Length (2)	Width (3)	Area (4)	Volume (5)	Volume (6)	Random (7)	Nr Boxes (8)
No Sort (0)	74.21 75.75	x	x	x	x	x	0	x	0
Height (1)	x	78.74- 80.28	x	x	x	x	x	x	x
Length (2)	x	x	84.88- 86.42	0	0	0	x	x	x
Width (3)	x	x	0	84.54- 86.08	0	0	x	x	x
Area (4)	x	x	0	0	86.45- 87.99	x	x	x	x
Volume (5)	x	x	0	0	x	83.34- 84.88	x	x	x
Total Vol. (6)	0	x	x	x	x	x	74.56 76.10	x	x
Random (7)	x	x	x	x	x	x	x	70.65- 72.19	0
Nr Boxes (8)	0	x	x	x	x	x	x	0	72.37- 73.91

Number of Turns

	0	1	2	3	4	5	6
0	77.69- 79.44	0	0	0	0	x	x
1	0	77.16 78.90	0	0	0	x	x
2	0	0	77.42- 79.16	0	0	x	x
3	0	0	0	79.07- 80.81	0	0	0
4	0	0	0	0	79.19- 80.93	0	0
5	x	x	x	0	0	80.29- 82.03	0
6	x	x	x	0	0	0	80.51- 82.26

RANGE TEST RESULTS AND MEANS CONFIDENCE INTERVALS LOADING WITHOUT STANDARD PALLETS

TABLE XII

	No Sort (0)	Height (1)	Length (2)	Width (3)	Area (4)	Volume (5)	Volume (6)	Random (7)	Nr Boxes (8)
No Sort (0)	52.44- 54.92	x	0	0	0	0	0	0	0
Height (1)	x	56.50- 59.98	x	0	0	x	0	0	0
Length (2)	0	x	51.38- 53.86	x	0	0	x	0	0
Width (3)	0	0	x	55.26- 57.74	0	x	0	0	0
Area (4)	0	0	0	0	54.16- 56.64	0	0	0	0
Volume (5)	0	x	0	x	0	51.80- 54.28	x	0	0
Total Vol. (6)	0	0	x	0	0	x	55.30- 57.78	0	0
Random (7)	0	0	0	0	0	0	0	53.87- 56.36	0
Nr Boxes (8)	0	0	0	0	0	0	0	0	53.27- 55.75

Number of Turns

	0	1	2	3	4	5	6
0	51.53- 53.65	x	x	x	x	x	x
1	x	54.45- 56.57	0	0	0	0	0
2	x	0	54.10- 56.22	0	0	0	0
3	x	0	0	54.09- 56.21	0	0	0
4	x	0	0	0	54.47- 56.59	0	0
5	x	0	0	0	0	54.47- 56.59	0
6	x	0	0	0	0	0	54.52- 56.64

RANGE TEST RESULTS AND MEANS CONFIDENCE INTERVALS LOADING WITH STANDARD PALLETS

TABLE XIII

STUFFING ALGORITHM FORTRAN COMPUTER PROGRAM

```
C        PROGRAM- STUFFING ALGORITHM
C        PROGRAMMER- N. B. NELSON
C        DATE WRITTEN-SUMMER 1979
C        MACHINE UPON WHICH RUN- IBM 360/60
C        METHOD OF RUNNING-COMPLIED AND WRITTEN TO DISK (LINK EDITED)
C        DESCRIPTION OF INPUT VARIABLES                                 TD 00010
C          CARD NUMBER 1 PARAMETERS                                     TD 00020
C             NR OF OPTIMIZATION LOOPS                                  TD 00030
C          CARD NUMBER 2 PARAMETERS                                     TD 00040
C             MAX TURNS OF BOX ALLOWED                                  TD 00050
C          CARD NUMBER 3 PARAMETERS                                     TD 00060
C             SORT CONTROL DIRECTION (SEE INPUT SUBROUTINE)             TD 00070
C          CARD NUMBER 4 PARAMETERS                                     TD 00080
C             STACKING CONTROL PARAMETER                                TD 00090
C                            CONTINUE                                   TD 00100
C           CARD NUMBER 5 PARAMETERS                                    TD 00110
C             PLMIN-IF BOX EXCEEDS THIS LENGTH, BOX                     TD 00120
C             ITSELF IS USED FOR PALLET BASE                            TD 00130
C             PWMIN-SAME AS ABOVE FOR WIDTH                             TD 00140
C             PL-STANDARD PALLET LENGTH                                 TD 00150
C             PW-STANDARD PALLET WIDTH                                  TD 00160
C             PH-MAXIMUM PALLET HEIGTH                                  TD 00170
C             CONL-CONTAINER LENGTH                                     TD 00180
C             CONW-CONTAINER WIDTH                                      TD 00190
C             CONH-CONTAINER HEIGTH                                     TD 00200
C                            CONTINUE                                   TD 00210
C           CARD NUMBER 6 (ONWARDS) PARAMETERS                          TD 00220
C             BOX ID NUMBER                                             TD 00230
C             NUMBER OF BOXES ON THIS LINE (SAME DIMENSIONS)            TD 00240
C             BOX LENGTH                                                TD 00250
C             BOX WIDTH                                                 TD 00260
C             BOX HEIGTH                                                TD 00270
                             CONTINUE                                   TD 00280
C        SUBROUTINES USED IN PROGRAM                                    TD 00290
C             INISH-INITIALIZE VARIABLES                                TD 00300
C             INPUT-READ INPUT VARIABLES                                TD 00310
C             PRT...-PRINTS ALL RESULTS (HAS ENTRY POINTS)              TD 00320
C             SORTIN-SORTS INPUTS OF BOX SIZES                          TD 00330
C             NEWPAL-STARTS A NEW PALLET                                TD 00340
C             LOAD-DOES THE FOLLOWING                                   TD 00350
C                  -SELECTS NEXT BOX                                    TD 00360
C                  -SELECTS NEXT ORIGIN                                 TD 00370
C                  -PALLITIZE THE BOX                                   TD 00380
```

```
C          -TURN THE BOX                                                TD 00390
C     STUFF-LOAD (STUFF) THE PALLETS IN THE CONTAINER                   TD 00400
C     GETEFF-CALCULATES EFFICIENCY OF THE LOADING                       TD 00410
C     RESETC- RESET ARRARY C TO SEQUENCE FRICR TC LAST SORT             TD 00420
C     SHUFL-SHUFFLES THE ORDER OF ARRAY C                               TD 00430
C     VSORTP-SORTS INPUT DATA                                           TD 00440
C     GETIME-GETS ELAPSED TIME                                          TD 00450
C     ITIME-TIME OF DAY IN HUNDREDTHS OF SECOND                         TD 00460
                          CONTINUE                                      TD 00470
C ARRAYS USED IN THE PROGRAM                                            TD 00480
C     A-LIST THE ID OF BOX, THE ORIGIN OF BOX, AND                      TD 00490
C          THE POSSIBLE STACKING POSITIONS CFF THE BOX                  TD 00500
C     B-LOGICAL ARRAY WHICH POINTS TO POSSIBLE ORIGINS                  TD 00510
C          WHICH ARE LISTED IN A                                        TD 00520
C     C-INPUT ARRAY-LISTS EACH LINE OF INFUT(BOXES)                     TD 00530
C     E-PALLET ARRAY-STORES INFO ON PALLETS                             TD 00540
                          CONTINUE                                      TD 00550
C LOGICAL VRIABLES USED IN PROGRAM                                      TD 00560
C     FIRST-INDICATES IF THIS IS FIRST PALLET TO LOAD                   TD 00570
C     ALLGON-ALL BOXES HAVE BEEN LOADED                                 TD 00580
C     OUTSIZ-AT LEAST ONE BOX IS OUTSIZE TO MIN PALLET                  TD 00590
C          PARAMENTERS                                                  TD 00600
C     TRIED-ALL BOXES HAVE BEEN TRIED (TO LCAD) AT  THIS                TD 00610
C          ORIGIN                                                       TD 00620
C     TURNED-BOX WAS TURNED                                             TD 00630
C     STUFED-THE CONTAINER STUFFING OPERATION HAS BEGUN                 TD 00640
                          CONTINUE                                      TD 00650
C OTHER VARIABLES USED IN THE PRCGRAM                                   TD 00660
C     BOXL-BOX LENGTH                                                   TD 00670
C     BOXW-BOX WIDTH                                                    TD 00680
C     BOXH-BOX HEIGTH                                                   TD 00690
C     CONL-CONTAINER LENGTH                                             TD 00700
C     CCNW-CONTAINER WIDTH                                              TD 00710
C     CONH-CONTAINER HEIGTH                                             TD 00720
C     IAP-POINTS TO CURRENT ROW OF A                                    TD 00730
C     IBPR-POINTS TO ROW OF B                                           TD 00740
C     IBPC-POINTS TO COLUMN OF B                                        TD 00750
C     IEP-POINTS TO ROW OF E                                            TD 00760
C     ICP-POINTS TO ROW OF C                                            TD 00770
C     MXTURN-MAXIMUM TURNS OF THE BOX WHICH IS                          TD 00780
C          PERMITTED (5 ARE POSSIBLE)                                   TD 00790
                          CONTINUE                                      TD 00800
C     NL-NUMBER OF INPUT LINES (TO ARRAY C)                             TD 00810
C     NRTURN-COUNTS THE TIMES A BOX HAS BEEN TURNED                     TD 00820
C     NXORG-NEXT X ORIGIN TO TRY                                        TD 00830
C     NYORG-NEXT Y ORIGIN TO TRY                                        TD 00840
C     NZORG-NEXT Z ORIGIN TO TRY                                        TD 00850
C     PALL-PALLET DIMENSIONS (CURRENT)                                  TD 00860
```

```
C              PALW-PALLET WIDTH                                              TD 00870
C              PALH-PALLET HEIGHT                                             TD 00880
C              PL-'STANDARD' PALLET LENGTH                                    TD 00890
C              PW-'STANDARD' PALLET WIDTH                                     TD 00900
C              PH-'STANDARD' PALLET HEIGTH                                    TD 00910
C              PLMIN-INPUT PARAMENTER-MIN PALLET LENGTH                       TD 00920
C              PWMIN-MIN PALLET WIDTH                                         TD 00930
C              RPH-ACCUMULATES TIME                                           TD 00940
C              TIME-ACCUMULATES TIME TO LOAD ALL PALLETS                      TD 00950
C              VOLUME-ACCUMULATES VOLUME OF ALL BOXES LOADED                  TD 00960
C                   ON EACH PALLET                                            TD 00970
C         MAIN PROGRAM
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                                  T  00010
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                       T  00020
      CCMMON ALLGCN,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,                T  00030
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                       T  00040
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P                  T  00050
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME                   T  00060
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT    00070
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                            T  00080
      CCMMON A(10C0,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),             T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                               T  00100
      OSEFF = 0.                                                             T  00101
      RPH = 0.                                                               T  00110
      XTPXT = 0.                                                             T  00115
C              SET NUMBER OF OPTIMIZATICN LOOPS                              T  00120
C              FOR LOADING PALLETS INTC CONTAINER                            T  00130
C              (MINIMUM NUMBER MUST BE 1)                                    T  00140
      NSLOOP = 1                                                             T  00150
C                                                                            T  00170
C                                                                            T  00180
C              INITIALIZE COMMON BLOCK                                       T  00190
      CALL INISH                                                             T  00200
C              READ IN GENERAL PARAMETERS AND                                T  00210
C              SPECIFIC BOX SIZES                                            T  00220
      CALL INPUT                                                             T  00230
C              PRINT INPUT DATA                                              T  00240
      CALL PRTIN                                                             T  00250
C              SORT ARRAY C (BOXES TO LOAD)                                  T  00260
C              AND PRINT AGAIN INPUT DATA (SORTED)                           T  00270
      CALL SORTIN                                                            T  00280
      CALL PRTINS                                                            T  00290
C              START AT NEW PALLET BUT FIRST PRINT                           T  00300
C              RESULTS OF LAST PALLET (IF THIS NCT BE FIRST)                 T  00310
  105 CONTINUE                                                               T  00320
      IF (.NOT.FIRST) CALL PRTPAL                                            T  00330
```

```
      CALL NPALL                                                         T   00340
C             SELECT NEXT BOX TO LOAD. IFF BOXES ARE                     T   00350
C             ALL GONE GONE GO PRINT STATS. IFF ALL                      T   00360
C             BOXES HAVE BEEN TRIED START A NEW PALLET.                  T   00370
  110 CONTINUE                                                           T   00380
      CALL LOAD (&105)                                                   T   00390
  125 CONTINUE                                                           T   00400
C             NO MORE BOXES ARE LEFT TO LOAD.                            T   00410
      IF (PRINT) CALL PRTPST                                             T   00420
C             NOW STUFF CONTAINER BY CALLING STUFF                       T   00430
C             CALL PRTSTF ON FIRST TIME THROUGH                          T   00440
      IF (PRINT .AND. .NOT.STUFED) CALL PRTSTF                           T   00450
C             NOW TURN OFF PRINT CONTROL                                 T   00460
C             UNTIL STUFFING OPTIMAZATION OF                             T   00470
C             STUFFING PALLETS INTO CONTAINER IS FINISH                  T   00480
      IF (.NOT. STUFED) CALL STUFF                                       T   00490
C             NOW OPTIMIZE LOADING OF PALLETS BY                         T   00500
C             MEANS OF IMPROVING SEARCH OF NSLOOP DIFFERENT SEQUENCES    T   00510
C             OF PALLET STUFFING                                         T   00520
      PRINT = .FALSE.                                                    T   00530
      IF (.NOT. STUFED) GO TO 149                                        T   00535
      NRSTF = NRSTF + 1                                                  T   00536
      OPSTUF = .TRUE.                                                    T   00537
      CALL GETEFF                                                        T   00538
      IF (SEFF .GE. OSEFF) GO TO 130                                     T   00539
      CALL RESTO                                                         T   00561
      GO TO 135                                                          T   00562
  130 CONTINUE                                                           T   00563
      OSEFF = SEFF                                                       T   00564
  135 CONTINUE                                                           T   00565
      IF (NRSTF .EQ. NSLOOP .AND. PRELON) GO TO 147                      T   00590
      IF (NRSTF .GT. NSLOOP) GO TO 150                                   T   00600
      GO TO 148                                                          T   00610
  147 CONTINUE                                                           T   00620
      PRINT = .TRUE.                                                     T   00630
      GO TO 149                                                          T   00640
  148 CONTINUE                                                           T   00650
      CALL SHUFL                                                         T   00660
  149 CONTINUE                                                           T   00670
      CALL INISH2                                                        T   00680
      STUFED = .TRUE.                                                    T   00690
      OLTSIZ = .FALSE.                                                   T   00700
      MXTURN = 1                                                         T   00710
C             REPLACE SECOND COLUMN OF C WHICH WAS DEPLETED              T   00720
C             IN LOADING SUBROUTINE.                                     T   00730
      DO 155 I=1,NL                                                      T   00740
      C(I,2) = 1                                                         T   00750
  155 CONTINUE                                                           T   00760
```

```
      GO TO 105                                                         T   00770
  150 CONTINUE                                                          T   00780
C                RESET COUNTER FOR OPTIMIZATION OF                      T   00790
C                STUFFING (LOADING PALLETS INTO CONTAINER               T   00800
      NRSTF = 0                                                         T   00810
C                NOW OPTIMIZE ENTIRE LOADING BY MEANS OF                T   00820
C                IMPROVING SEARCHES OF 'NRLOAD' DIFFERENT               T   00830
C                SEQUENCES OF INPUT BOX LINES.                          T   00840
      CALL GETIME(IET)                                                  T   00850
      CALL RESETC                                                       T   00860
      NRPLT = NRPLT + 1                                                 T   00870
      OPSTUF = .FALSE.                                                  T   00880
      STUFED = .FALSE.                                                  T   00891
      IF (OSEFF .GE. TEFF) GO TO 152                                    T   00892
      CALL RESTO                                                        T   00893
      GO TO 154                                                         T   00894
  152 CONTINUE                                                          T   00895
      TEFF = OSEFF                                                      T   00896
  154 CONTINUE                                                          T   00897
      IF (NRPLT .GT. NRLOOP) GO TO 160                                  T   00900
      CALL SHUFL                                                        T   00920
      XT = IET * .000026                                                T   00930
      CUMTIM = CUMTIM + XT                                              T   00940
      WRITE (30,180) NRPLT,TEFF, XT, CUMTIM                             T   00950
      CALL INISH2                                                       T   00960
      CALL SETIME                                                       T   00970
      GO TO 105                                                         T   00980
  160 CONTINUE                                                          T   00990
C                OPTIMIZATION IS COMPLETED SO LOOP                      T   01000
C                BACK THRU AND PRINT RESULTS AS THEY                    T   01010
C                ARE REALIZED  (PROVIDED OPTIMIZATION WAS DONE.)        T   01020
      IF (PRELON) GO TO 165                                             T   01030
      PRINT = .TRUE.                                                    T   01050
      PRELON = .TRUE.                                                   T   01060
      CALL INISH2                                                       T   01070
      RPH = CUMTIM                                                      T   01080
      GO TO 105                                                         T   01090
  165 CONTINUE                                                          T   01100
      SEFF = TEFF                                                       T   01110
      CALL PRTFIN                                                       T   01120
      STOP                                                              T   01130
  180 FORMAT (I8,4F8.3)                                                 T   01140
      END                                                               T   01180
```

```
      SUBROUTINE INISH                                                  T  01190
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T  01200
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T  01210
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T  01220
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                  T  01230
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T  01240
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T  01250
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT  01260
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T  01270
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T  00100
      CALL SETIME                                                       T  01300
      TEFF = 0.                                                         T  01310
      NRLOOP = 1                                                        T  01320
      PRINT = .FALSE.                                                   T  01330
      PRELON = .FALSE.                                                  T  01340
      NRPLT = 0                                                         T  01350
      NRSTF = 0                                                         T  01360
      CUMTIM = 0.                                                       T  01370
      VOLIN = 0.                                                        T  01380
      SEFF = 0.                                                         T  01390
      ISEED = 12345                                                     T  01400
      ENTRY INISH2                                                      T  01410
      TIME = 0.                                                         T  01420
      NXORG = 1                                                         T  01430
      NYORG = 1                                                         T  01440
      NZORG = 1                                                         T  01450
      STUFED = .FALSE.                                                  T  01460
      FIRST = .TRUE.                                                    T  01470
      OUTSIZ = .TRUE.                                                   T  01480
      NRTURN = 1                                                        T  01490
      NBOX = 1                                                          T  01500
      VOLUME = 0.                                                       T  01510
      TIME = 0.                                                         T  01520
      IAP = 1                                                           T  01530
      ICP = 1                                                           T  01540
      IEP = 0                                                           T  01550
      IOUTIN = 1                                                        T  01560
      RETURN                                                            T  01570
C&    DEBUG SUBCHK,SUBTRACE,INIT,UNIT(30),TRACE                         T  01580
      END                                                               T  01590
```

```
      SUBROUTINE INPUT                                                  T   01600
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T   01610
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T   01620
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T   01630
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBOX,NRPERM,NRTURN,                  T   01640
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T   01650
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T   01660
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT   01670
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELCN,IAPEFF                       T   01680
      COMMON  A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),       T   00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T   00100
C             READ GENERAL PROBLEM PARAMENTERS                          T   01710
C                  READ CARD NR 1.                                      T   01720
C                       NR OPTIMIZE LOOPS                               T   01730
C                         (F10.0)                                       T   01740
      READ (5,315) XX                                                   T   01750
      NRLOOP = IFIX(XX)                                                 T   01760
C             IF NO OPTIMIZATION IS DESIRED,                            T   01770
C             PRINT RESULTS OF LOADING AS IT OCCURS                     T   01780
      IF (NRLOOP .LE. 0) PRINT = .TRUE.                                 T   01790
      IF (NRLOOP .LE. 0 ) PRELON = .TRUE.                               T   01800
C                  READ CARD NR 2                                       T   01810
C                       MAX TURNS OF BOX                                T   01820
C                         (I1)                                          T   01830
      READ (5,320) MXTURN                                               T   01840
      IMXT = MXTURN                                                     T   01850
C                  READ CARD NR 3                                       T   01860
C                       SORT CONTROL                                    T   01870
C                         (I2)                                          T   01880
      READ (5,321) ISORT                                                T   01890
C                  READ CARD NR 4                                       T   01900
C                       STACKING CONTROL (T=NO OVERHANG)                T   01910
C                                        (F=OVERHANG)                   T   01920
C                         (L1)                                          T   01930
      READ (5,322) GRAVTY                                               T   01940
C                  READ CARD NR 5                                       T   01950
C                       LENGTH,WIDTH WHICH IF EXCEED                    T   01960
C                       CAUSES BOX TO BE PALLET;                        T   01970
C                       LENGTH,WIDTH,HEIGHT OF STANDARD PALLET          T   01980
C                       LENGTH,WIDTH,HEIGHT OF CONTAINER.               T   01990
C                         (F10.0)                                       T   02000
      READ (5,315) PLMIN,PWMIN,PL,PW,PH,CONL,CONW,CONH                  T   02010
C                             .                                         T   02020
C             READ EACH BOX (ID,NR,L,W,H) (DSRN=1)                      T   02030
C                             .                                         T   02040
      NL = 0                                                            T   02050
  305 CONTINUE                                                          T   02060
C                             .                                         T   02070
```

```
      NL = NL + 1
      READ (1,315,END=370) ((C(NL,I),I=2,5),XX)
C             IF FLAG IS SET ON THIS LINE, DO NOT LET
C             THIS BOX BE USED AS A BASE FOR OTHER BOXES
C             (IE, THIS BOX IS A NON-LOAD BEARING BOX).
      STACK(NL) = .TRUE.
      IF (XX .EQ. 1.) STACK(NL) = .FALSE.
C             NOW SET LENGTH TO MAX (LENGTH,WIDTH)
      IF (C(NL,3) .GE. C(NL,4)) GO TO 307
      XX = C(NL,3)
      C(NL,3) = C(NL,4)
      C(NL,4) = XX
  307 CONTINUE
      C(NL,1) = NL
      DO 306 I=1,5
      CHOLD(NL,I) = C(NL,I)
  306 CONTINUE
      VOLIN = C(NL,2) * C(NL,3) * C(NL,4) * C(NL,5) + VOLIN
C                            .
C             NOW ESTABLISH THE SORTING VECTOR (SORVEC)
C             AS DIRECTED BY INPUT VARIABLE, SORT, AS FOLLOWS:
C                            .
C                ISORT    SORT BY (LARGEST TO SMALLEST)
C                  0      (NO SORT)
C                  1      HEIGHT
C                  2      LENGTH
C                  3      WIDTH
C                  4      AREA (LXW)
C                  5      VOLUME(LXWXH)
C                  6      TOT VOL (LXWXHXNR)
C                  7      RANDOM SORT
C                  8      NR (BOXES PER LINE)
C                  9      (INVERSE ORDER OF READ-IN)
C                 10      RANDOM SORT (WITH RANDOM SEED)
C                            .
      IF (ISORT .EQ. 0) GO TO 305
      GO TO (325,330,335,340,345,350,355,360,365,355),ISORT
      GO TO 340
  325 CONTINUE
      SORVEC(NL) = C(NL,5)
      GO TO 305
  330 CONTINUE
      SORVEC(NL) = C(NL,3)
      GO TO 305
  335 CONTINUE
      SORVEC(NL) = C(NL,4)
      GO TO 305
  340 CONTINUE
```

```
      SORVEC(NL) = C(NL,4) * C(NL,3)                                    T  02560
      GO TO 305                                                         T  02570
  345 CONTINUE                                                          T  02580
      SORVEC(NL) = C(NL,4)*C(NL,3)*C(NL,5)                              T  02590
      GO TO 305                                                         T  02600
  350 CONTINUE                                                          T  02610
      SORVEC(NL) = C(NL,4)*C(NL,3)*C(NL,5)*C(NL,2)                      T  02620
      GO TO 305                                                         T  02630
  355 CONTINUE                                                          T  02640
C             CAUTION.  FOLLOWING RANDOM GENERATOR IS RATHER POOR       T  02650
C                       AND DESIGNED FOR IBM 360 HARDWARE ONLY.         T  02660
C                       HOWEVER, IT IS VERY FAST.                       T  02670
C             IF SORT BE SET TO RANDOM SEED                             T  02785
C             SET ISEED RANDOMLY BY USING CURRENT TIME                  T  02790
C             OF DAY IN HUNDREDTHS OF SECS.(ISEED SHOULD BE ODD INTEGER)T  02800
      IF (NL .LE. 1 .AND. ISORT .EQ. 10) ISEED=ITIME(XX)/2*2+1          T  02810
      ISEED = ISEED * 65539                                             T  02680
      IF (ISEED .LT. 0) ISEED = ISEED + 2147483647 + 1                  T  02690
      SORVEC(NL) = ISEED                                                T  02700
      GO TO 305                                                         T  02710
  360 CONTINUE                                                          T  02720
      SORVEC(NL) = C(NL,2)                                              T  02730
      GO TO 305                                                         T  02740
  365 CONTINUE                                                          T  02750
      SORVEC(NL) = NL                                                   T  02760
      GO TO 305                                                         T  02770
  370 CONTINUE                                                          T  02830
      NL = NL - 1                                                       T  02840
C             RESET ISEED TO RANDOM NUMBER FOR USE IN REST OF PROGRAM   T  02850
      ISEED = ITIME(XX) / 2 * 2 + 1                                     T  02855
      RETURN                                                            T  02880
C&       DEBUG SUBCHK,SUBTRACE,INIT,UNIT(30),TRACE                      T  02890
C&    AT 305                                                            T  02900
C&    TRACE ON                                                          T  02910
C                                                                       T  02920
C                                                                       T  02930
C                                                                       T  02940
  315 FORMAT (8F10.0)                                                   T  02950
  320 FORMAT (I1)                                                       T  02960
  321 FORMAT (I2)                                                       T  02970
  322 FORMAT (L1)                                                       T  02980
      END                                                               T  02990
```

```
      SUBROUTINE SORTIN                                                 T 03000
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T 03010
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T 03020
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T 03030
     1 IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBOX,NRPERM,NRTURN,                 T 03040
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T 03050
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T 03060
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT 03070
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELCN,IAPEFF                       T 03080
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T 00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T 00100
      DIMENSION CS(500,5)                                               T 03110
      DIMENSION IPER(500)                                               T 03120
C             IF SORT NOT DESIRED RETURN TO MAIN                        T 03130
      IF (ISORT .EQ. 0) RETURN                                          T 03140
C             SET UP WORKING SORT ARRAY AND                             T 03150
C             INDEX ARRAY                                               T 03160
      KEND = NL+1                                                       T 03170
      IENDSO = IFIX(FLOAT(NL) / 2. + .6)                                T 03180
C                                                                       T 03190
C                                                                       T 03200
C                                                                       T 03210
      DO 410 I=1,NL                                                     T 03220
      K = KEND-I                                                        T 03230
C                                                                       T 03240
C                                                                       T 03250
C                                                                       T 03260
      DO 405 J=1,5                                                      T 03270
      CS(I,J) = C(K,J)                                                  T 03280
  405 CONTINUE                                                          T 03290
C                                                                       T 03300
C                                                                       T 03310
C                                                                       T 03320
      IPER(I) = I                                                       T 03330
      IF (I .GT. IENDSO) GO TO 410                                      T 03340
      XX = SORVEC(I)                                                    T 03350
      SORVEC(I) = SORVEC(K)                                             T 03360
      SORVEC(K) = XX                                                    T 03370
  410 CONTINUE                                                          T 03380
C                                                                       T 03390
C                                                                       T 03400
C                                                                       T 03410
C             NOW SORT BY ORDER OF SORVEC                               T 03420
      CALL VSRTR (SORVEC,NL,IPER)                                       T 03430
C             NOW REWRITE C WITH LARGEST VALUE FIRST                    T 03440
C                                                                       T 03450
C                                                                       T 03460
C                                                                       T 03470
```

```
      DO 420 K=1,NL                                                     T   03480
      I = KEND-K                                                        T   03490
C                                                                       T   03500
C                                                                       T   03510
C                                                                       T   03520
      DO 415 J=1,5                                                      T   03530
      XX = CS(IPER(I),J)                                                T   03540
      C(K,J) = XX                                                       T   03550
      CHOLD(K,J) = XX                                                   T   03560
  415 CONTINUE                                                          T   03570
C                                                                       T   03580
C                                                                       T   03590
C                                                                       T   03600
  420 CONTINUE                                                          T   03610
C                                                                       T   03620
C                                                                       T   03630
C                                                                       T   03640
      RETURN                                                            T   03650
C&             DEBUG SUBCHK,SUBTRACE,INIT(C,K),UNIT(30),TRACE           T   03660
C&    AT 405                                                            T   03670
C&    TRACE ON                                                          T   03680
      END                                                               T   03690
```

```
      SUBROUTINE NPALL                                                  T   03700
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T   03710
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T   03720
      COMMON  ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,          T   03730
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                  T   03740
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T   03750
     3RINT,PLMIN,PWMIN,PPH,STUFED,TIME,TRIED,TURNED,VOLUME              T   03760
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT   03770
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T   03780
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T   00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T   00100
  705 CONTINUE                                                          T   03810
      FIRST = .FALSE.                                                   T   03820
      VOLUME = 0.                                                       T   03830
      PALH = 0.                                                         T   03840
C              RESET POINTER AND LOGICAL USED IN GETBOX                 T   03850
      ICP = 1                                                           T   03860
C              SET A ARRAY POINTER                                      T   03870
C              BUT FIRST RECORD ITS VALUE FOR USE IN GETEFF S.R.        T   03880
      IAPEFF = IAP                                                      T   03890
      IAP = 0                                                           T   03900
      B(1,1) = .TRUE.                                                   T   03910
C              IF NO BOXES ARE OUTSIZE USE PREVIOUS DEFAULT VALUES      T   03920
      IF (.NOT.OUTSIZ) GO TO 720                                        T   03930
C              CHECK TO SEE IF BOX LARGER THAN                          T   03940
C              MAX ALLOWABLE SIZE EXISTS                                T   03950
C              IF SO, USE FOR PALLET BASE                               T   03960
C                                                                       T   03970
C                                                                       T   03980
C                                                                       T   03990
      DO 710 I=IOUTIN,NL                                                T   04000
      IF (C(I,2).GT.0..AND.(C(I,3).GT.PLMIN.OR.C(I,4).GT.PWMIN)) GO TO 7T   04010
     115                                                                T   04020
  710 CONTINUE                                                          T   04030
C                                                                       T   04040
C                                                                       T   04050
C                                                                       T   04060
      PALL = PL                                                         T   04070
      PALW = PW                                                         T   04080
      OLTSIZ = .FALSE.                                                  T   04090
      GO TO 720                                                         T   04100
  715 CONTINUE                                                          T   04110
      IOUTIN = I                                                        T   04120
C              FOUND AN OUTSIZED BOX. LOAD THIS BOX                     T   04130
C              AND ADJUST PALLET DIMENSIONS.                            T   04140
C              LOAD ID INTO ARRAY A                                     T   04150
      A(1,1) = C(1,1)                                                   T   04160
C              LOAD X,Y,Z INTO A                                        T   04170
```

```
      A(1,2) = 0.                                                        T   04180
      A(1,3) = 0.                                                        T   04190
      A(1,4) = 0.                                                        T   04200
C             LOAD L,W,H INTO A                                          T   04210
      A(1,5) = C(I,3)                                                    T   04220
      A(1,6) = C(I,4)                                                    T   04230
      A(1,7) = C(I,5)                                                    T   04240
C             UPDATE B ARRAY                                             T   04250
      B(1,3) = .TRUE.                                                    T   04260
C             SET PALET DIMENSIONS                                       T   04270
      PALL = C(I,3)                                                      T   04280
      PALW = C(I,4)                                                      T   04290
C             POSITION A POINTER                                         T   04300
      IAP = 1                                                            T   04310
C             NOW SUBTRACT THIS BOX FROM C                               T   04320
      C(I,2) = C(I,2)-1                                                  T   04330
      VOLUME = PALL*PALW*C(I,5)                                          T   04340
  720 CONTINUE                                                           T   04350
C             SELECT SMALLEST PERMISSIBLE MARGINS                        T   04360
C             IN X,Y, AND Z DIRECTIONS                                   T   04370
      SMLX = 2.E6                                                        T   04380
      SMLY = 2.E6                                                        T   04390
      SMLZ = 2.E6                                                        T   04400
C                                                                        T   04410
C                                                                        T   04420
C                                                                        T   04430
      DO 725 I=1,NL                                                      T   04440
      IF (C(I,2).LE.0) GO TO 725                                         T   04450
      IF (C(I,3).LT.SMLX) SMLX=C(I,3)                                    T   04460
      IF (C(I,4).LT.SMLY) SMLY=C(I,4)                                    T   04470
      IF (C(I,5).LT.SMLZ) SMLZ=C(I,5)                                    T   04480
  725 CONTINUE                                                           T   04490
C                                                                        T   04500
C                                                                        T   04510
C                                                                        T   04520
      IF (MXTURN.LE.0.) GO TO 730                                        T   04530
      SMLX = AMIN1(SMLX,SMLY)                                            T   04540
      SMLY = SMLX                                                        T   04550
      IF (MXTURN.EQ.1) GO TO 730                                         T   04560
      SMLX = AMIN1(SMLX,SMLZ)                                            T   04570
      SMLY = SMLX                                                        T   04580
      SMLZ = SMLX                                                        T   04590
  730 CONTINUE                                                           T   04600
      RETURN                                                             T   04610
C&    DEBUG SUBTRACE,TRACE,SUBCHK,INIT,UNIT(30)                          T   04620
C&    AT 710                                                             T   04630
C&    TRACE ON                                                           T   04640
      END                                                                T   04650
```

```
      SUBROUTINE LOAD(*)                                                T    04660
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T    04670
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T    04680
      LOGICAL CHANGE, SOMCHG, CHECKD                                    T    04690
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T    04700
     1 IAP, ICP, IEP,MXTURN,OPSTUF,NL,NBOX,NRPERM,NRTURN,               T    04710
     2     NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW, PALH,PL,PW,PH,P          T    04720
     3R INT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME             T    04730
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT    04740
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T    04750
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T    00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T    00100
C               .                                                       T    04780
C               AREA FOR SELECTION OF BOX                               T    04790
C               .                                                       T    04800
  500 CONTINUE                                                          T    04810
C               RESET NRTURN USED IN TURN                               T    04820
C               RESET POINTER TO NEW ORIGIN                             T    04830
      IF (OUTSIZ) GO TO 505                                             T    04840
      NXORG = 1                                                         T    04850
      NYORG = 1                                                         T    04860
      NZORG = 1                                                         T    04870
      GO TO 510                                                         T    04880
  505 CONTINUE                                                          T    04890
      NXORG = 2                                                         T    04900
      NYORG = 2                                                         T    04910
      NZORG = 1                                                         T    04920
  510 CONTINUE                                                          T    04930
      NRTURN = 1                                                        T    04940
C               SELECT THE NEXT BOX WHICH IS NOT                        T    04950
C               OUTSIZED TO PALLET  IN BOTH DIMENSION                   T    04960
      IF (ICP.EQ.1) ALLGON=.TRUE.                                       T    04970
C                                                                       T    04980
C                                                                       T    04990
C                                                                       T    05000
      DO 515 I=ICP,NL                                                   T    05010
      IF (C(I,2).LE.0.) GO TO 515                                       T    05020
      IF (C(I,3).LE.PALL.OR.C(I,4).LE.PALW) GO TO 525                   T    05030
      IF (ICP.EQ.1) ALLGON=.FALSE.                                      T    05040
  515 CONTINUE                                                          T    05050
C                                                                       T    05060
C                                                                       T    05070
C                                                                       T    05080
  520 CONTINUE                                                          T    05090
C               IF ALL BOXES ARE GONE (LOADED) DROP                     T    05100
C               THRU TO PRINT SUBROUTINE                                T    05110
      IF (ALLGON .AND. .NOT. OUTSIZ) RETURN                             T    05120
C               ALL BOXES HAVE BEEN TRIED AT THIS PALLET                T    05130
```

```
C             THEREFORE, GO START ANOTHER PALLET
      RETURN 1
  525 CONTINUE
C             BOX HAS BEEN FOUND.  RECORD LINE
C             NUMBER,L,W,H OF BOX AS TAKEN
C             FROM ARRAY C.
      IF (ICP.EQ.1) ALLGON=.FALSE.
      ICP = I
      BOXL = C(I,3)
      BOXW = C(I,4)
      BOXH = C(I,5)
C             END OF AREA TO GET BOX
C                            .
C                            .
C             AREA TO DETERMINE ORIGIN
C                            .
C             IF A STANDARD PALLET IS BEING USED
C             SELECT THE CORNER (0,0,0) AS
C             THE ORIGIN AND GO DIRECT TO PALLETIZE
  600 CONTINUE
      IF (IAP.GE.1) GO TO 605
      ORX = 0.
      ORY = 0.
      ORZ = 0.
      IBPR = 1
      IBPC = 1
      GO TO 800
  605 CONTINUE
      IF (NXORG.GT.IAP) GO TO 615
C             TRY FOR X POSITION FIRST
C
C
C
      DO 610  IBPR=NXORG,IAP
      IF (.NOT.B(IBPR,1)) GO TO 610
      IF ((A(IBPR,5)+BOXL).GT.PALL) GO TO 610
      IF ((A(IBPR,3)+BOXW).GT.PALW) GO TO 610
      IF ((A(IBPR,4)+BOXH).GT.PH) GO TO 610
      GO TO 640
  610 CONTINUE
C
C
C
      NXORG = IAP+1
  615 CONTINUE
C             SINCE NO MORE X POSTIONS TRY FOR Y POSITION
      IF (NYORG.GT.IAP) GO TO 625
C
```

```
C                                                                              T  05620
C                                                                              T  05630
      DO 620  IBPR=NYORG,IAP                                                   T  05640
      IF (.NOT.B(IBPR,2)) GO TO 620                                            T  05650
      IF ((A(IBPR,6)+BOXW).GT.PALW) GO TO 620                                  T  05660
      IF ((A(IBPR,2)+BOXL).GT.PALL) GO TO 620                                  T  05670
      IF ((A(IBPR,4)+BOXH).GT.PH) GO TO 620                                    T  05680
      GO TO 645                                                                T  05690
  620 CONTINUE                                                                 T  05700
C                                                                              T  05710
C                                                                              T  05720
C                                                                              T  05730
      NYORG = IAP+1                                                            T  05740
  625 CONTINUE                                                                 T  05750
C             SINCE NO Y POSITIONS, TRY FOR Z                                  T  05760
C             PROVIDED STUFFING OPERATION IS NOT                               T  05770
C             GOING ON (SINCE PROGRAM ARBATARILY DECIDED                       T  05780
C             NOT TO STACK PALLETS).                                           T  05790
      IF (.NOT. STUFED .AND. NZORG.LE.IAP) GO TO 630                           T  05800
C             THERE ARE NO ORIGINS AVAIL                                       T  05810
C             SO GO TURN THE BOX                                               T  05820
      GO TO 900                                                                T  05830
  630 CONTINUE                                                                 T  05840
C                                                                              T  05850
C                                                                              T  05860
C                                                                              T  05870
      DO 635 IBPR=NZORG,IAP                                                    T  05880
      IF (.NOT.B(IBPR,3)) GO TO 635                                            T  05890
      IF ((A(IBPR,7)+BOXH).GT.PH) GO TO 635                                    T  05900
      IF ((A(IBPR,2)+BOXL).GT.PALL) GO TO 635                                  T  05910
      IF ((A(IBPR,3)+BOXW).GT.PALW) GO TO 635                                  T  05920
      GO TO 650                                                                T  05930
  635 CONTINUE                                                                 T  05940
C                                                                              T  05950
C                                                                              T  05960
C                                                                              T  05970
C             THERE ARE NO ORIGINS AVAIL                                       T  05980
C             SO GO TURN THE BOX                                               T  05990
      GO TO 900                                                                T  06000
  645 CONTINUE                                                                 T  06010
      NYORG = IBPR+1                                                           T  06020
      ORX = A(IBPR,2)                                                          T  06030
      ORY = A(IBPR,6)                                                          T  06040
      ORZ = A(IBPR,4)                                                          T  06050
      IBPC = 2                                                                 T  06060
C             FOUND AN ORIGIN NOW GO LOAD BOX                                  T  06070
      GO TO 800                                                                T  06080
  650 CONTINUE                                                                 T  06090
```

```
      NZORG = IBPR+1                                                    T   06100
      ORX = A(IBPR,2)                                                   T   06110
      ORY = A(IBPR,3)                                                   T   06120
      ORZ = A(IBPR,7)                                                   T   06130
      IBPC = 3                                                          T   06140
C             FOUND AN ORIGIN NOW LOAD BOX                              T   06150
      GO TO 800                                                         T   06160
  640 CONTINUE                                                          T   06170
      NXORG = IBPR+1                                                    T   06180
      ORX = A(IBPR,5)                                                   T   06190
      ORY = A(IBPR,3)                                                   T   06200
      ORZ = A(IBPR,4)                                                   T   06210
      IBPC = 1                                                          T   06220
C             FOUND AN ORIGIN NOW LOAD BOX                              T   06230
C             END OF AREA TO GET ORIGIN                                 T   06240
C                                 .                                     T   06250
C                                 .                                     T   06260
C             AREA TO TRY TO PALLETIZE BOX                              T   06270
C                                 .                                     T   06280
  800 CONTINUE                                                          T   06290
C             SEE IF BOX WILL FIT                                       T   06300
      ORXPL = ORX+BOXL                                                  T   06310
      ORYPW = ORY+BOXW                                                  T   06320
      ORZPH = ORZ+BOXH                                                  T   06330
C             IF THIS IS FIRST BOX AND SINCE IT MUST                    T   06340
C             FIT THE PALLET, LOAD IT NOW                               T   06350
      IF (IAP.LE.0) GO TO 835                                           T   06360
C             IF BOX WILL NOT FIT GO GET ANOTHER ORIGIN                 T   06370
C             IMPROVE THE DENSITY IF POSSIBLE                           T   06380
C             DO THIS BY FINDING A BOX THAT WILL                        T   06390
C             INITIALLY FIT AND THEN PROGRESSIVELY MOVE                 T   06400
C             THE BOX TO THE LEFT,DOWN, AND TOWARD THE                  T   06410
C             THE FRONT, IF POSSIBLE.  THAT IS,                         T   06420
C             MOVE THE BOX TOWARD THE FIXED ORIGIN.  REPEAT             T   06430
C             UNTIL NO FUTHER IMPROVEMENT IS POSSIBLE IN                T   06440
C             ANY OF THE 3 DIRECTIONS.                                  T   06450
      SCMCHG = .FALSE.                                                  T   06460
      CHECKD = .FALSE.                                                  T   06470
  700 CONTINUE                                                          T   06480
      CHANGE = .FALSE.                                                  T   06510
C             FIND MOST RESTRICTING BOX IN LOWER Y DIRECTION            T   06520
C             IN ORDER TO SEE IF BOX WILL FIT AND TO                    T   06530
C             SEEK AN IMPROVEMENT. (HOWEVER, NO IMPROVEMENT             T   06540
C             IS POSSIBLE IF ORY IS ALREADY AT                          T   06550
C             ITS MIN (0) OR ORIGIN IS AN 'Y' ORIGIN (IBPC=2).          T   06560
      IF (.NOT. SCMCHG .AND. IBPC .EQ. 2) GO TO 711                     T   06570
      IF (ORY .EQ. 0) GO TO 711                                         T   06580
      SLACK = ORY                                                       T   06590
```

```
      CHECKD = .TRUE.                                                   T   06600
      DO 710 I=1,IAP                                                    T   06610
      IF (  A(I,2) .GE. ORXPL .OR. A(I,5) .LE. ORX .OR.                 T   06620
     .      A(I,4) .GE. ORZPH .OR. A(I,7) .LE. ORZ .OR.                 T   06630
     .      A(I,3) .GE. ORYPW) GO TO 710                                T   06640
      IF (  A(I,6) .LE. ORY) GO TO 705                                  T   06650
C                 GO GET ANOTHER ORIGIN                                 T   06660
      GO TO 605                                                         T   06670
  705 CONTINUE                                                          T   06680
      XYZ = ORY - A(I,6)                                                T   06690
      IF (SLACK .GT. XYZ) SLACK = XYZ                                   T   06700
  710 CONTINUE                                                          T   06710
      IF (SLACK .LT. 1.) GO TO 711                                      T   06720
      CHANGE = .TRUE.                                                   T   06730
      SOMCHG = .TRUE.                                                   T   06740
      ORY = ORY - SLACK                                                 T   06750
      ORYPW = ORYPW - SLACK                                             T   06760
  711 CONTINUE                                                          T   06770
C                 FIND MOST RESTRICTING BOX IN DOWN Z DIRECTION         T   06780
C                 SIMILAR TO ABOVE SEARCH FOR Y DIRECTION               T   06790
      IF (ORZ .EQ. 0) GO TO 721                                         T   06800
      IF (.NOT. SOMCHG .AND. IBPC .EQ. 3) GO TO 721                     T   06810
      SLACK = ORZ                                                       T   06820
      CHECKD = .TRUE.                                                   T   06830
      DO 720 I=1,IAP                                                    T   06840
      IF (A(I,2) .GE. ORXPL .OR. A(I,5) .LE. ORX .OR.                   T   06850
     .    A(I,3) .GE. ORYPW .OR. A(I,6) .LE. ORY .OR.                   T   06860
     .    A(I,4) .GE. ORZPH) GO TO 720                                  T   06870
      IF (A(I,7) .LE. ORZ) GO TO 715                                    T   06880
      GO TO 605                                                         T   06890
  715 CONTINUE                                                          T   06900
      XYZ = ORZ - A(I,7)                                                T   06910
      IF (SLACK .GT. XYZ) SLACK = XYZ                                   T   06920
  720 CONTINUE                                                          T   06930
      IF (SLACK .LT. 1.) GO TO 721                                      T   06940
      CHANGE = .TRUE.                                                   T   06950
      SOMCHG = .TRUE.                                                   T   06960
      ORZ = ORZ - SLACK                                                 T   06970
      ORZPH = ORZPH - SLACK                                             T   06980
  721 CONTINUE                                                          T   06990
C                 C FIND MOST RESTRICTING BOX IS LEFT X                 T   07000
C                 DIRECTION SIMILAR TO ABOVE TWO SEARCHES               T   07010
C                 HOWEVER, MAKE SURE THE LOCATION IS CHECKED            T   07020
C                 AT LEAST ONCE.                                        T   07030
      IF (.NOT. CHECKD) GO TO 722                                       T   07040
      IF (ORX .EQ. 0.) GO TO 736                                        T   07050
      IF (.NOT. SOMCHG .AND. IBPC .EQ. 1) GO TO 736                     T   07060
  722 CONTINUE                                                          T   07070
```

```
      SLACK = ORX                                                       T  07080
      CHECKD = .TRUE.                                                   T  07090
      DO 730 I=1,IAP                                                    T  07100
      IF (A(I,4) .GE. ORZPH .OR. A(I,7) .LE. ORZ .OR.                   T  07110
     .    A(I,3) .GE. ORYPW .OR. A(I,6) .LE. ORY .OR.                   T  07120
     .    A(I,2) .GE. ORXPL) GO TO 730                                  T  07130
      IF (A(I,5) .LE. ORX) GO TO 725                                    T  07140
      GO TO 605                                                         T  07150
  725 CONTINUE                                                          T  07160
      XYZ = ORX - A(I,5)                                                T  07170
      IF (SLACK .GT. XYZ) SLACK = XYZ                                   T  07180
  730 CONTINUE                                                          T  07190
      IF (SLACK .LT. 1) GO TO 736                                       T  07200
      CHANGE = .TRUE.                                                   T  07210
      SCMCHG = .TRUE.                                                   T  07220
      ORX = ORX -SLACK                                                  T  07230
      ORXPL = ORXPL - SLACK                                             T  07240
  736 CCNTINUE                                                          T  07250
C             NOW IF ANY CHANGE HAS OCCURED DURING THE                  T  07260
C             ABOVE SEARCHES, LOOP BACK AND TRY TO FIND                 T  07270
C             MCRE IMPRCVEMENT IN OTHER CIRECTIONS.                     T  07280
      IF (CHANGE) GO TO 700                                             T  07290
C                                                                       T  07350
C                                                                       T  07360
C                                                                       T  07370
C             IF GRAVITY IS A PROBLEM, SEE IF BOX                       T  07380
C             WILL HAVE A BASE UPON WHICH TO REST                       T  07390
C             CHECK EACH BOX AT HEIGTH 'ORZ' AT                         T  07400
C             EACH OF THE 4 CORNERS OF BOX:                             T  07410
C             (BUT DO NOT USE A NCN-LOAD BEARING BOX)                   T  07420
C                                                                       T  07430
C               LOOP     POINT                                          T  07440
C                 1      (ORX,ORY)                                      T  07450
C                 2      (ORX + BOXL,ORY)                               T  07460
C                 3      (ORX,ORY + BOXW)                               T  07470
C                 4      (ORX + BOXL,ORY + BOXW)                        T  07480
C                                                                       T  07490
      IF (.NOT.GRAVTY.OR.ORZ.EQ.0..OR.OUTSIZ.AND.ORZ.EQ.A(1,7)) GO TO 83T  07500
     15                                                                 T  07510
      XX = ORX                                                          T  07520
      YY = ORY                                                          T  07530
C                                                                       T  07540
C                                                                       T  07550
C                                                                       T  07560
      DC 830 J=1,4                                                      T  07570
C                                                                       T  07580
C                                                                       T  07590
C                                                                       T  07600
```

```
      DO 810 I=1,IAP                                                    T  07610
      IF (.NOT. STACK(I)) GO TO 810                                     T  07620
      IF (A(I,7).NE.ORZ) GO TO 810                                      T  07630
      IF (A(I,2).LE.XX.AND.A(I,5).GE.XX.AND.A(I,3).LE.YY.AND.A(I,6).GE.YT  07640
     1Y) GO TO 815                                                      T  07650
  810 CONTINUE                                                          T  07660
C                                                                       T  07670
C                                                                       T  07680
C                                                                       T  07690
C             BOX HAS NO SUPPORT, THEREFORE, CAN NOT PALLETIZE,         T  07700
C             GO GET ANOTHER ORIGIN                                     T  07710
      GO TO 605                                                         T  07720
  815 CONTINUE                                                          T  07730
      IF (J.LE.1) GO TO 825                                             T  07740
      IF (J.LE.2) GO TO 820                                             T  07750
      XX = ORXPL                                                        T  07760
      GO TO 830                                                         T  07770
  820 CONTINUE                                                          T  07780
      XX = ORX                                                          T  07790
      YY = ORYPW                                                        T  07800
      GO TO 830                                                         T  07810
  825 CONTINUE                                                          T  07820
      XX = ORXPL                                                        T  07830
  830 CONTINUE                                                          T  07840
C                                                                       T  07850
C                                                                       T  07860
  835 CONTINUE                                                          T  07870
C                                                                       T  07880
C             BOX IS SUPPORTED                                          T  07890
C             THIS ORIGIN (ORX,ORY,ORZ) WILL NOT RESTRICT               T  07900
C             THE BOX'S LOADING. RECORD THE BOX IN ARRAY A              T  07910
      IAP = IAP+1                                                       T  07920
      A(IAP,2) = ORX                                                    T  07930
      A(IAP,3) = ORY                                                    T  07940
      A(IAP,4) = ORZ                                                    T  07950
      A(IAP,5) = ORXPL                                                  T  07960
      A(IAP,6) = ORYPW                                                  T  07970
      A(IAP,7) = ORZPH                                                  T  07980
C             NOW SUBTRACT BOX FROM ARRAY C                             T  07990
      C(ICP,2) = C(ICP,2)-1                                             T  08000
C             NOW UPDATE LOGICAL ARRAY B (THIS POINT                    T  08010
C             IS NOW FILLED) AND ESTABLISH THE                          T  08020
C             3 NEW POSSIBLE ORIGINS                                    T  08030
      IF (IAP.GT.1) B(IBPR,IBPC)=.FALSE.                                T  08040
      B(IAP,1) = .TRUE.                                                 T  08050
      B(IAP,2) = .TRUE.                                                 T  08060
      B(IAP,3) = .TRUE.                                                 T  08070
C             OVERIDE THESE TRUE SETTTINGS OF ORIGINS IF                T  08080
```

```
C               NO BOX CAN POSSIBLY FIT
      IF ((PALL-ORXPL).LT.SMLX) B(IAP,1)=.FALSE.
      IF ((PALW-ORYPW).LT.SMLY) B(IAP,2)=.FALSE.
      IF ((PH-ORZPH).LT.SMLZ) B(IAP,3)=.FALSE.
C               RECORD HEIGHT, CUMULATIVE VOLUME OF PALLET
      IF (.NOT. PRINT) GO TO 500
      VOLUME = VOLUME+BCXL*BOXW*BOXH
      A(IAP,1) = C(ICP,1)
      IF (ORZPH .GT. PALH) PALH = ORZPH
C               BOX WAS PALLETIZED SO GO GET
C               ANOTHER BOX
      GC TO 500
C               BOX WILL NOT FIT AT THIS CRIGIN
C                                .
C               END OF AREA TO PALLETIZE
C                                .
C                                .
C               AREA TO TURN BOX
C                                .
  900 CONTINUE
      IF (NRTURN.GT.MXTURN) GO TO 915
C               RESET POINTERS USED IN GETORG
      IF (OUTSIZ) GO TO 905
      NXORG = 1
      NYORG = 1
      NZORG = 1
      GO TO 910
  905 CONTINUE
      NXORG = 2
      NYORG = 2
      NZORG = 1
  910 CCNTINUE
      TL = BOXL
      TW = BOXW
      TH = BOXH
C               INCREASE NR OF TURNS BY 1.
C               DO NOT EXCEED MXTURN
C               TURNS ARE AS FOLLOWS
C                                .
C               NRTURN  X  Y  Z
C                 -     L  W  H
C                 1     W  L  H
C                 2     W  H  L
C                 3     L  H  W
C                 4     H  L  W
C                 5     H  W  L
C                                .
      GO TO (920,925,93C,935,940,915), NRTURN
```

```
C             THERE ARE NO MORE TURNS LEFT                              T  08570
  915 CONTINUE                                                          T  08580
C             IF ICP=NL THERE ARE NO MORE BOXES LET                     T  08590
C             TO TRY.  THEREFORE, GO GET ANOTHER PALLET.                T  08600
      IF (ICP .EQ. NL) RETURN 1                                         T  08610
C             INCREASE ICP IN ORDER TO SELECT                           T  08620
C             THE NEXT LINE WHEN GETBOX IS REENTERED.                   T  08630
      ICP = ICP+1                                                       T  08640
C             GO GET ANOTHER BOX                                        T  08650
      GO TO 500                                                         T  08660
  920 CONTINUE                                                          T  08670
      IF (BOXL.GT.PALW.OR.BOXW.GT.PALL) GO TO 925                       T  08680
      NRTURN = 2                                                        T  08690
      BOXL = TW                                                         T  08700
      BOXW = TL                                                         T  08710
C             BOX WAS TURNED. GO GET AN ORIGIN                          T  08720
      GO TO 605                                                         T  08730
  925 CONTINUE                                                          T  08740
      IF (MXTURN.LE.2) GO TO 915                                        T  08750
      IF (BOXH.GT.PALW) GO TO 935                                       T  08760
      NRTURN = 3                                                        T  08770
      BOXL = TW                                                         T  08780
      BOXW = TH                                                         T  08790
      BOXH = TL                                                         T  08800
C             BOX WAS TURNED. GO GET AN ORIGIN                          T  08810
      GO TO 605                                                         T  08820
  930 CONTINUE                                                          T  08830
      NRTURN = 4                                                        T  08840
      BOXL = TL                                                         T  08850
      BOXW = TH                                                         T  08860
      BOXH = TW                                                         T  08870
C             BOX WAS TURNED. GO GET AN ORIGIN                          T  08880
      GO TO 605                                                         T  08890
  935 CONTINUE                                                          T  08900
      IF (MXTURN.LE.4) GO TO 915                                        T  08910
      IF (BOXH.GT.PALL) GO TO 915                                       T  08920
      NRTURN = 5                                                        T  08930
      BOXL = TH                                                         T  08940
      BOXW = TL                                                         T  08950
      BOXH = TW                                                         T  08960
C             BOX WAS TURNED. GO GET AN ORIGIN                          T  08970
      GO TO 605                                                         T  08980
  940 CONTINUE                                                          T  08990
      NRTURN = 6                                                        T  09000
      BOXL = TH                                                         T  09010
      BOXW = TW                                                         T  09020
      BOXH = TL                                                         T  09030
C             BOX WAS TURNED. GO GET AN ORIGIN                          T  09040
```

```
      GO TO 605                                                          T   09050
C                                                                        T   09060
C             END CF AREA TO TURN BOX                                    T   09070
C&    DEBUG SUBTRACE,TRACE,SUBCHK,INIT,UNIT(30)                          T   09090
C&    AT 500                                                             T   09100
C&    TRACE ON                                                           T   09110
      END                                                                T   09120
```

```
      SUBROUTINE PRT                                                    T  09130
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T  09140
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T  09150
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T  09160
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                  T  09170
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T  09180
     3RINT,PLMIN,PWMIN,PPH,STUFED,TIME,TRIED,TURNED,VOLUME              T  09190
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLFOLD,NRSTF,IMXTT  09200
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T  09210
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T  00100
      RETURN                                                            T  09240
C               ENTRY POINT FOR PRINTING INPUT DATA                     T  09250
      ENTRY PRTIN                                                       T  09260
C               PRINT INPUT DATA                                        T  09270
      WRITE (6,1025) PLMIN,PWMIN,PL,PW,PH,CONL,CONW,CONH,MXTURN,NRLOOP,ITT  09280
     1SORT,GRAVTY                                                       T  09290
      WRITE(20,1025) PLMIN,PWMIN,PL,PW,PH,CONL,CONW,CONH,MXTURN,NRLOOP,ITT  09300
     1SORT,GRAVTY                                                       T  09310
      WRITE (20,1020)                                                   T  09320
      WRITE (20,1045)                                                   T  09330
      GO TO 1005                                                        T  09340
C                                                                       T  09350
      ENTRY PRTINS                                                      T  09360
      CALL SETIME                                                       T  09370
      IF (ISORT .EQ. 0) RETURN                                          T  09380
C                                                                       T  09390
      WRITE (6,1075)                                                    T  09400
 1005 CONTINUE                                                          T  09410
      WRITE (6,1030) ((C(I,J),J=1,5),I=1,NL)                            T  09420
      CALL SETIME                                                       T  09430
      RETURN                                                            T  09440
C                                                                       T  09450
C               ENTRY POINT FOR PALLET STATS                            T  09460
C                                                                       T  09470
      ENTRY PRTPST                                                      T  09480
      PALVOL = 0.                                                       T  09490
      TIME = 0.                                                         T   9510
      VOLUME = 0.                                                       T  09500
C                                                                       T  09510
C                                                                       T  09520
C                                                                       T  09530
      DO 1010 I=1,IEP                                                   T  09540
      VOLUME = VOLUME+E(I,5)                                            T  09550
      TIME = TIME+E(I,6)                                                T  09560
      PALVOL = PALVOL+E(I,2)*E(I,3)*E(I,4)                              T  09570
 1010 CONTINUE                                                          T  09580
C                                                                       T  09590
```

```
C                                                                        T   09600
C                                                                        T   09610
      RFH = RPH+TIME                                                     T   09620
      TOTEFF = VOLUME/PALVOL*100.                                        T   09630
      WRITE (20,1035) VOLUME,PALVOL,TIME,TOTEFF                          T   09640
      WRITE (6,1040)                                                     T   09650
      WRITE (6,1035) VOLUME,PALVOL,TIME,TOTEFF                           T   09660
      RETURN                                                             T   09670
C                                                                        T   09680
C             ENTRY POINT FOR DETAILEC PALLET INFCRMATION                T   09690
C                                                                        T   09700
      ENTRY PRTPAL                                                       T   09710
C                                                                        T   09720
C             NOW STORE RESULTS OF LAST PALLET                           T   09730
      IEP = IEP + 1                                                      T   09740
      E(IEP,2) = PALL                                                    T   09750
      E(IEP,3) = FALW                                                    T   09760
      FIRST = .FALSE.                                                    T   09770
      IF (.NOT. PRINT) RETURN                                            T   09780
      CALL GETIME(IET)                                                   T   09790
      E(IEP,1) = IEP                                                     T   09800
      E(IEP,4) = PALH                                                    T   09810
      E(IEP,5) = VOLUME                                                  T   09820
      E(IEP,6) = IET*.000026                                             T   09830
      WRITE (6,1040)                                                     T   09840
      EFF = VCLUME/(PALL*PALW*PH)*100.                                   T   09850
      WRITE (6,1045) ((E(IEP,J),J=1,6),EFF)                              T   09860
      WRITE (20,1070) ((E(IEP,J),J=1,6),EFF)                             T   09870
      WRITE (6,1050)                                                     T   09880
C                                                                        T   09890
C                                                                        T   09900
C                                                                        T   09910
      DO 1015 I=1,IAP                                                    T   09920
      BLL = A(I,5)-A(I,2)                                                T   09930
      BWW = A(I,6)-A(I,3)                                                T   09940
      BFH = A(I,7)-A(I,4)                                                T   09950
      WRITE (6,1055) (A(I,1),BLL,BWW,BHH,(A(I,J),J=2,7))                 T   09960
 1015 CONTINUE                                                           T   09970
C                                                                        T   09980
C                                                                        T   09990
C                                                                        T   10000
C                                                                        T   10010
C                                                                        T   10020
      CALL SETIME                                                        T   10030
      RETURN                                                             T   10040
C                                                                        T   10050
C             ENTRY POINT TO PRINT START OF STUFFING                     T   10060
C                                                                        T   10070
```

```
      ENTRY PRTSTF                                                      T 10080
      WRITE (6,1060)                                                    T 10090
      WRITE (20,1060)                                                   T 10100
      RETURN                                                            T 10110
C                                                                       T 10120
C             ENTRY POINT FOR FINAL STATS                               T 10130
C                                                                       T 10140
      ENTRY PRTFIN                                                      T 10150
      WRITE (6,1065) RPH,SEFF                                           T 10160
      WRITE (20,1065) RPH,SEFF                                          T 10170
C                                                                       T 10180
C                                                                       T 10190
      RETURN                                                            T 10200
C&       DEBUG SUBCHK,SUBTRACE,INIT,UNIT(30),TRACE                      T 10210
C                                                                       T 10220
 1020 FORMAT (' SUMMARY LINE FOR EACH PALET THAT WAS STACKED'/////)     T 10230
 1025 FORMAT ('1FOLLOWING ARE INPUT PARAMENTERS:'///                    T 10240
     1 ' MINIMUM PALLET LENGTH=',F10.3//                                T 10250
     2 ' MINIMUM PALLET WIDTH=',F10.3//                                 T 10260
     3 ' NORMAL PALLET LENGTH=',F10.3//                                 T 10270
     4 ' NORMAL PALLET WIDTH=',F10.3//                                  T 10280
     5 ' NORMAL PALLET HEIGTH=',F10.3//                                 T 10290
     6 ' CONTAINER LENGTH =',F10.3//                                    T 10300
     7 ' CONTAINER WIDTH =',F10.3//                                     T 10310
     8 ' CONTAINER HEIGHT =',F10.3//                                    T 10320
     9 ' MAX NR OFTURNS (6 POSSIBLE)=',I10//                            T 10330
     $ ' NUMBER OF OPTIMIZATION LOOPS= ',I10//                          T 10340
     $ ' SORT CONTROL VARIABLE=',I10//                                  T 10350
     $ ' LOGICAL GRAVITY VARIABLE=',L10/'1')                            T 10360
 1030 FORMAT (' FOLLOWING IS AN ECHO PRINT OF BOXES'//                  T 10370
     1' NR LINE     NR BOXES  LENGTH     WIDTH      HEIGHT'//           T 10380
     2 (5F10.3))                                                        T 10390
 1035 FORMAT (////' TOTAL BOX VOLUME=',F12.2//' TOTAL PALLET VOLUME =', T 10400
     1 F12.1// ' TOTAL ELAPSED TIME (IN SECS)=',F12.2//                 T 10410
     2' TOTAL %  EFFICIENCY =',F12.2)                                   T 10420
 1040 FORMAT ('1')                                                      T 10430
 1045 FORMAT (' PALLET NUMBER LENGTH      WIDTH      HEIGHT',           T 10440
     1' VOLUME        TIME   % EFFICIENCY'// 8F10.1)                    T 10450
 1050 FORMAT (////' FOLLOWING BOXES WERE STACKED'//                     T 10460
     1'   ID  NR  LENGTH   WIDTH  HEIGTH     X         Y        Z  ',   T 10470
     2' X+BOXL  Y+BOXW   Z+BOXH'//)                                     T 10480
 1055 FORMAT (/,   10F8.1)                                              T 10490
 1060 FORMAT(///'1 ALL BOXES HAVE BEEN LOADED.  THE BELOW PRINTOUT'/    T 10500
     1' REFERS TO THE STUFFING OF THE VAN.'/' THUS, ',                  T 10510
     2'THE VAN MAY BE TAKEN AS THE PALLET AND THE PALLET THE BOX.')     T 10520
 1065 FORMAT (//////'1 NORMAL TERMINATION OF PROGRAM.'/                 T 10530
     1 ' TOTAL ELAPSED TIME FOR BOTH PALLET LOADING AND VAN',           T 10540
     2' STUFFING WAS (SECS):',F8.2///                                   T 10550
```

```
    3' GRAND EFFICIENCY (%) (TOTAL BCX VOL/TOTAL CCNT VCL) =',           T  10560
    4  F8.2)                                                             T  10570
 1070 FCRMAT (8F10.2/)                                                   T  10580
 1075 FORMAT ('1NOW AFTER SORTING:')                                     T  10590
      ENC                                                                T  10600
```

```
      SUBROUTINE STUFF                                                  T  10610
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T  10620
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T  10630
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T  10640
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                  T  10650
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T  10660
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T  10670
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT  10680
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T  10690
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500).                         T  00100
      DIMENSION IPER(500)                                               T  10720
C                                                                       T  10740
C              MOVE THE PALLETS INTO ARRAY C .                          T  10750
C              BUT DO NOT ALLOW STUFFING IN Z DIRECTION                 T  10760
C              (IE NOT NOT STACK) BY MAKING PALLET HEIGHT               T  10770
C              THE CONTAINER HEIGHT.                                    T  10780
C                                                                       T  10790
C                                                                       T  10800
C              NOW PRIOR TO LOADING C, SORT E ARRAY                     T  10810
C              BY WIDTH                                                 T  10820
      DO 1100  I=1,IEP                                                  T  10830
      IPER(I) = I                                                       T  10840
      IF (E(I,3) .GE. E(I,2) ) GO TO 1100                               T  10835
      XX =E(I,2)                                                        T  10836
      E(I,2) = E(I,3)                                                   T  10837
      E(I,3) = XX                                                       T  10838
 1100 CONTINUE                                                          T  10850
      CALL VSRTR (E(1,3),IEP,IPER)                                      T  10860
C                                                                       T  10870
      IEPP1 = IEP + 1                                                   T  10880
      DO 1105 K=1,IEP                                                   T  10890
      I = IEPP1 - K                                                     T  10900
      IX = IPER(I)                                                      T  10910
      C(K,1) = E(IX,1)                                                  T  10920
      C(K,2) = 1                                                        T  10930
      C(K,3) = E(IX,2)                                                  T  10940
      C(K,4) = E(I,3)                                                   T  10950
      C(K,5) = CONH                                                     T  10960
 1105 CONTINUE                                                          T  10970
C                                                                       T  10980
C                                                                       T  10990
C                                                                       T  11000
      C((IEP+1),2) = 0                                                  T  11010
      NLHOLD = NL                                                       T  11020
      NL = IEP                                                          T  11030
      PALH = CONH                                                       T  11040
      PALL = CONL                                                       T  11050
```

```
      PALW = CONW                                                       T   11060
      RETURN                                                            T   11070
C&    DEBUG SUBCHK,SUBTRACE,INIT(NLHOLD,NL,PALH,PALL,PALW,C,STUFED,     T   11080
C&   .OUTSIZ,MXTURN,IX), UNIT (30), TRACE                               T   11090
      END                                                               T   11100
```

```
      SUBROUTINE GETEFF                                                 T  11110
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T  11120
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T  11130
      COMMON ALLGCN,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T  11140
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                  T  11150
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T  11160
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T  11170
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT  11180
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T  11190
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T  00100
C             FIND MAX WIDTH UTILIZED                                   T  11220
      XW = 0.                                                           T  11230
      DO 10 I=1,IAPEFF                                                  T  11240
      IF (A(I,6) .GT. XW) XW = A(I,6)                                   T  11250
   10 CONTINUE                                                          T  11260
      SEFF = VOLIN /((IEP-1 + XW /CONW) * CONL*CONW*CONH) * 100.        T  11270
      RETURN                                                            T  11350
C&    DEBUG INIT,TRACE,SUBCHK,SUBTRACE,UNIT(30)                         T  11360
      END                                                               T  11370
```

```
      SUBROUTINE RESETC                                                 T  11380
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T  11390
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T  11400
      CCMMON ALLGCN,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T  11410
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBCX,NRPERM,NRTURN,                  T  11420
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T  11430
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T  11440
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT  11450
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T  11460
      CCMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T  00100
      NL = NLHOLD                                                       T  11490
      MXTURN = IMXT                                                     T  11500
C             RESTORE C WHICH WAS DESTROYED BY                          T  11510
C             STUFFING SUBROUTINE OR BY UNSUCCESSFUL                    T  11520
C             OPTIMIZATION OVERALL (AS OPPOSED TO                       T  11530
C             OPTIMIZATION OF PALLET LOADING INTO                       T  11540
C             CONTAINER)                                                T  11550
      DO 20 I= 1,NL                                                     T  11560
      CC 10 J=1,5                                                       T  11570
      C(I,J) = CHCLD(I,J)                                               T  11580
   10 CCNTINUE                                                          T  11590
   20 CCNTINUE                                                          T  11600
      RETURN                                                            T  11610
C&    DEBUG INIT, TRACE, SUBCHK,SUBTRACE,UNIT(30)                       T  11620
      END                                                               T  1163C
```

```
      SUBROUTINE SHUFL                                                  T  11640
      LOGICAL ALLGON,B,FIRST,OUTSIZ,OPSTUF,                             T  11650
     1PRINT,PRELON,STACK,STUFED,GRAVTY                                  T  11660
      COMMON ALLGON,BOXL,BOXW,BOXH,CONL,CONW,CONH,FIRST,HIGH,           T  11670
     1IAP,ICP,IEP,MXTURN,OPSTUF,NL,NBOX,NRPERM,NRTURN,                  T  11680
     2    NXORG,NYORG,NZORG,OUTSIZ,PALL,PALW,PALH,PL,PW,PH,P            T  11690
     3RINT,PLMIN,PWMIN,RPH,STUFED,TIME,TRIED,TURNED,VOLUME              T  11700
     4,ISORT,GRAVTY,SMLX,SMLY,SMLZ,IOUTIN,NRLOOP,VOLIN,NLHOLD,NRSTF,IMXTT  11710
     5,TEFF,NRPLT,SEFF,CUMTIM,ISEED,PRELON,IAPEFF                       T  11720
      COMMON A(1000,7),B(1000,3),C(500,5),CHOLD(500,5),E(300,6),        T  00090
     1HCP(300),HCS(300),STACK(500),SORVEC(500)                          T  00100
      DIMENSION HCPHOL(300),HCSHOL(300)                                 T  00101
      N =.025*NL + 1                                                    T  11750
      ANL=NL                                                            T  11760
      DO 40 K=1,N                                                       T  11770
C             CAUTION:  SEE  SUBROUTIN INPUT FOR WARNING ON             T  11780
C                       USE OF FOLLOWING RN GENERATOR                   T  11790
      ISEED = ISEED * 65539                                             T  11800
      IF (ISEED .LT. 0) ISEED = ISEED + 2147483647 + 1                  T  11810
      I = IFIX (FLOAT(ISEED) * .4656613E-9 * ANL) + 1                   T  11820
      ISEED = ISEED * 65539                                             T  11830
      IF (ISEED .LT. 0) ISEED =  ISEED + 2147483647 + 1                 T  11840
      L = IFIX (FLOAT(ISEED) * .4656613E-9 * ANL) + 1                   T  11850
      IF (.NOT. OPSTUF) GO TO 25                                        T  11860
      HCP(K) = I                                                        T  11870
      HCS(K) = L                                                        T  11880
      GO TO 26                                                          T  11885
   25 CONTINUE                                                          T  11890
      HCPHOL(K) = I                                                     T  11891
      HCSHOL(K) = L                                                     T  11893
   26 CONTINUE                                                          T  11894
      DO 30 J=1,5                                                       T  11900
      XX = C(I,J)                                                       T  11910
      YY = C(L,J)                                                       T  11920
      C(I,J) = YY                                                       T  11930
      C(L,J) = XX                                                       T  11940
      IF (OPSTUF) GO TO 30                                              T  11950
C             RECORD C IN CHOLD BECAUSE SUBROUTINE                      T  11960
C             STUFF DESTROYED C.  ALSO, IF NEW                          T  11970
C             OPTIMIZATION TRY WHILE GENERAL                            T  11980
C             LOADING, MUST RESTORE C IF TRIAL IS UNSUCCESSFUL          T  11990
      CHOLD(L,J) = XX                                                   T  12000
      CHOLD(I,J) = YY                                                   T  12010
   30 CONTINUE                                                          T  12020
   40 CONTINUE                                                          T  12030
      RETURN                                                            T  12040
      ENTRY RESTO                                                       T  12045
C             NOW REVERSE THE SHUFFLE IN ORDER                          T  12180
```

```
C                 TO REPLACE THE ORIGINAL CRDER                            T   12190
C                 OF C                                                     T   12200
      N =.025* NL + 1                                                      T   12210
      NP1 = N + 1                                                          T   12220
      DC140 K=1,N                                                          T   12230
      M= NP1 - K                                                           T   12240
      IF (.NOT. OPSTUF) GO TO120                                           T   12245
      I = HCP(M)                                                           T   12250
      L = HCS(M)                                                           T   12260
      GC TO125                                                             T   12261
  12C CONTINUE                                                             T   12263
      I = HCPHOL(M)                                                        T   12264
      L= HCSHOL(M)                                                         T   12265
  125 CONTINUE                                                             T   12266
      DO130 J =1,5                                                         T   12270
      XX = C(I,J)                                                          T   12280
      YY = C(L,J)                                                          T   12290
      C(L,J) = XX                                                          T   12300
      C(I,J) = YY                                                          T   12310
      IF (OPSTUF) GO TO130                                                 T   12320
      CHOLD(L,J) = XX                                                      T   12330
      CHOLD(I,J) = YY                                                      T   12340
  130 CONTINUE                                                             T   12350
  140 CONTINUE                                                             T   12360
      RETURN                                                               T   12370
      END                                                                  T   12390
```

LIST OF REFERENCES

1. Brown, A. R., Optimum Packing and Depletion, Jeffreys and Hill Limited, 1971.

2. DeSha, Ernest Larry, Area-Efficient and Volume-Efficient Algorithms for Loading Cargo, M.S. Thesis, Naval Postgraduate School, Monterey, California, 1970.

3. Eilon, Samuel and Christofides, Nicos, "The Loading Problem," Management Science, Volume 17, Number 5, p 259-266, 1971.

4. Galata, A. Ya and Stoyan, Yu.G, "The Dense Packing of Parallelepipeds of Arbitrary Dimensions in a Parallelepiped of Least Volume," Cybernetics, Number 2, p 268-274, March 1972.

5. Gilmore, P. C. and R. E. Gomory, "A Linear Programming Approach to the Cutting Stock Problem-Part II," Operations Research, Volume 11, p 863-889, November 1963.

6. Gilmore, P. C. and Gomory, R. E., "The Theory and Computation of Knapsack Functions," Operations Research, Volume 14, p 1045-1074, November 1966.

7. Gilmore, P. C. and Gomory, R. E., "Multistage Cutting Stock Problems of Two and More Dimensions," Operations Research, Volume 13, p 94-119.

8. Ingargiola, Giorgio and Korsh, James F., "An Algorithm for the Solution of 0-1 Loading Problems," Operations Research, Volume 23, p 1110-1119, November 1975.

9. Rvachev, V. L. and Stoyan, Yu.G., "Algorithms for Constructing Inequalities Satisfied by the Location Parameters of Nonintersecting Bodies," Kibernetika, Volume 2, Number 6, p 82-92, 1966.

10. Department of Industrial and Systems Engineering, University of Florida, Gainsville, Report 40, Unitization and Deunitization in Physical Distribution Systems: A Qualitative and Quantitative Analysis of Containerized Cargo by Ravi M. Seam and B. D. Sivazlian, March 1970.

11. Stoyan, Yu.G. and Ponomarenko, L. D., "Algorithm for Approximate Solution of the Problem of Closest Packing of a Group of Parallelepipeds in a Parallelepiped with Forbidden Regions," Automatic Control and Computer Sciences, Volume 9, Number 1, p 41-48, 1975.

12. Camp, Gary L., Adapt Cargo Loading Algorithm to Navy Integrated Storage Tracking and Retrieval System (NISTARS), Staff Study at Naval School Transportation Management, Naval Supply Center, Oakland, California, March 1979.

13. Hicks, Charles R., Fundamental Concepts in the Design of Experiments, Holt, Rinehart, Winston, 1973.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 55 Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
4.	Associate Professor Alan W. McMasters Code 55Mg Department of Operations Research Naval Postgraduate School Monterey, California 93940	5
5.	LT. Ellen Roland, Code 55 Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
6.	LCDR N. B. Nelson III 2958 Hillsdale Drive Pleasant Hill, California 94523	3
7.	CDR Robert D. Grant Special Project Officer (Code 08) Naval Supply Center Oakland, California 94625	5
8.	Defense Logistics Studies Information Exchange U.S. Army Logistics Management Center Fort Lee, Virginia 23801	1
9.	Mr. H. J. Lieberman, Code 0431B Naval Supply Systems Command Washington, D. C. 20376	1

184975
Thesis
N3645 Nelson
c.1
A container stuffing algorithm for rectangular solids when voids may be required.

Thesis 184975
N3645 Nelson
c.1
A container stuffing algorithm for rectangular solids when voids may be required.

A container stuffing algorithm for recta
3 2768 000 98641 8
DUDLEY KNOX LIBRARY